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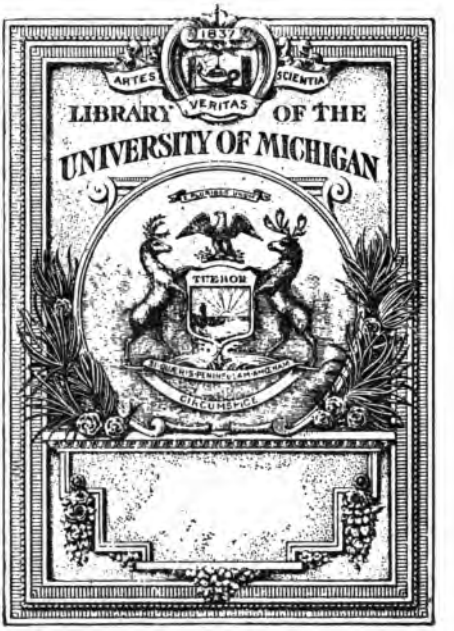
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THE NINETY-FIRST

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1905.

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THE

ANNIVERSARY ADDRESS OF THE PRESIDENT,

J. H. COLLINS, Esq., F.G.S.

To the General Meeting, October 25th, 1904.

Ladies and Gentlemen,—The healthy condition of the Society is clearly set forth in the official reports which have been presented to-day. We would like to see a larger membership, but so we should if we were ten times as numerous. Enough in such cases is "a little more than we have." Our *Transactions* maintain their interest and importance; in particular they are greatly valued and constantly referred to by writers in all parts of the world who are concerned with metalliferous deposits.

In the Report of the Council reference has been made to the very heavy loss which, in common with all who are interested in Mining and the sciences which are most closely allied with it, this Society has sustained through the death of our friend and late President, Sir Clement Le Neve Foster. Your loss is in an especial degree my loss, for certainly no one here present was brought into such intimate association with our deceased friend as myself. Our lives in many respects have run in parallel courses for a long series of years. We were born in the same month of the same year; we studied the same branches of science, though for the most part in very different schools. He preceded me as lecturer of the Miners' Association of Cornwall and Devon; I worked

with him as joint-Secretary of the Royal Institution of Cornwall; I succeeded him as Secretary of the Royal Cornwall Polytechnic Society, also as Curator and more recently as President of this Society. We lived for a time side by side in Truro; when he left Truro we corresponded constantly on many different subjects; he very often helped me; I was sometimes able to help him. As I have said elsewhere, our dear friend "afforded the most complete example of the union of the theoretical with the practical that I have ever been privileged to know. His experiences as Student, as Explorer, as Mine Manager, as Government Inspector, as Professor, as Editor, all helped and reinforced each other. In particular he was always profoundly interested in the vital question of the *cost* of the operations he conducted or described, and he took care to impress the importance of this subject upon his pupils. His numerous scientific papers and text-books are all highly instructive and very original, and his name will long be a household word wherever mining students take their work seriously. Many a now flourishing miner has reason to remember his kindness of heart—no trouble was too great to be spent upon a real student. His devotion to Science was remarkably shown in the Snaefell accident, when, while being slowly suffocated and having given up all hope of rescue, he wrote down his sensations minute by minute in his notebook as long as he could hold a pencil. He was rescued, but he never fully recovered from that evil experience, which no doubt was effective in shortening his life."

The region with which we are especially concerned, viz. Cornwall, and Devon to the west of Exeter, continues to interest geologists and mineralogists. Besides the papers contributed to our *Transactions* there have appeared during the past ten years numerous communications dealing with the geology, mineralogy, and mining of this Dumnonian region from many different writers in at least a dozen scientific journals. New fossils, minerals, and mineral varieties continue to be discovered, and it would be a very useful occupation for some young student to continue and bring up to date Mr. Whitaker's "List of Works on

the Geology, Mineralogy, and Palæontology of Cornwall," which was presented to the Royal Institution of Cornwall in the year 1874.[1]

The intricacy and complexity, as well as the surpassingly interesting character of our region, is plainly shown in this vast mass of work. I have myself been more or less engaged in the study of the region for more than thirty years, and as a result of these somewhat prolonged studies, I have arrived at certain conclusions which are embodied, together with a discussion of the facts upon which they are based, in a rather extensive work on the nature, origin, and history of our metalliferous deposits which is now nearly ready for the press. On this occasion it may be of interest to you if I set forth very briefly my main conclusions, without troubling you with any of the evidence on which I rely.

An outline of the geological structure of the West of England mineral region, as it is commonly accepted and understood, is given in Chapter I. of Book I. The remainder of this Book is employed in giving detailed accounts of the phenomena of many of the principal lodes and other mineral deposits, attention being also directed to certain general and special characters of the lodes and cross-courses, the succession of minerals found in the lodes, the mutual relations of lodes and country, and the geographical distribution of the elements and compounds within our region.

In Book II., Chapter I., some generally approved propositions in physical and chemical geology are briefly stated, and these in the subsequent chapters are freely used and applied to the interpretation and elucidation of the numerous facts which have been set forth in Book I. As a result, it is believed that, among others, the following propositions and conclusions will be seen to be fully justified and warranted.

(1) The main mass of the West of England peninsula consisted originally of extensive deposits of mud which were laid down in a deep sea, and of less extensive beds of pebbles and sand deposited in the shallows. The oldest of these beds are of pre-Devonian

[1] See *Journ. R. I. C.*, vol. v. pp. 61–110. A similar list for Devonshire by the same author appeared in the *Transactions of the Devonshire Association* in 1870, with a supplement in 1872.

age, some having been formed in Ordovician times and some perhaps much earlier. These early sediments do not appear to have been metalliferous to any important extent.

(2) During the greatly lengthened Devonian and Carboniferous periods the sea-bottom was mostly subsiding. Hence great thicknesses of deposits were accumulated which have been subsequently consolidated into shales, slates, sandstones, and limestones.

(3) In Devonian times, and probably also still earlier, several active or intermittent volcanoes were in existence in this region. When in eruption, these supplied lavas, mostly of a basic character, which were forced up through fissures (as dykes), or between the beds (as sills), or poured out over the sea-bottom so as to form interbedded sheets. The volcanoes also at times emitted vast quantities of "ash," which, falling into the sea, helped to fill it up with interstratifications of "ash-beds," while in times of quiescence, corals and other organisms grew and flourished in this sea.

(4) After the Devonian eruptions had ceased, a great thickness of carboniferous rocks was deposited upon the Devonian strata. During this period, also, volcanic eruptions took place on a considerable scale.

(5) Many of the eruptive rocks contain iron oxide (magnetite) in considerable quantities, which seems to have been an original constituent, and subsequently in some cases to have become segregated into lenticular beds, such as are seen in the cliffs near Botallack, at Treluswell, and at Haytor. Others of the lavas and ash-beds (as at Brent Tor and other places) are highly charged with manganese. Furthermore, a great deal of manganese and of pyritous matter is present in many of the Devonian slates and shales, especially in the tracts of country lying to the north of Tavistock and to the north and west of Exeter. In some places, too (as at the Bampfylde Mine, near North Molton, in Devon, and at Wheal Music, near Portreath, in Cornwall), a great deal of copper is present with the pyrites, so that thick beds of shale contain copper throughout in considerable proportions.

(6) In times of eruption the sea must have become greatly

charged with mineral substances of various kinds, so that the stratified rocks then formed must also have been metalliferous to some extent.[1]

(7) At several different times the deposits above described were compressed by extensive earth-movements into folds (geoclines), and finally elevated so as to form dry land. In West Cornwall these geoclines course from 20 to 30 degrees north of east; this is probably the most ancient system of geoclines of which we still find traces in this part of the world, and there can be little doubt that it was formed in early or pre-Devonian times. In East Cornwall and in Devon the principal geoclines course east, or even a few degrees south of east, and they were certainly formed after the close of the Carboniferous period. Other geoclines, having different directions, are traceable in several places, and these are probably of intermediate age. Much of the characteristic foliation, jointing, and cleavage of the rocks has been determined by these pressures.

(8) In post-Carboniferous times granitic material was forced up from below into the stratified rocks, and perhaps even reached the surface at certain points.[2] In the neighbourhood of Carn Brea, and probably in other parts of the district, the granite appears to have been so intruded as to form subterranean ridges at no great depths below the present surface, and, as might have been expected, the directions of those ridges were determined by the directions of the pre-existing geoclines. The granite has also invaded the surrounding stratified rocks in the form of veins, and has even caught up and enclosed fragments of those rocks, as may be seen at innumerable points.

(9) The granite was forced up from a great depth, and under

[1] The local charging of seas and lakes with metalliferous substance is a common circumstance even now; thus Mr. J. A. Phillips has calculated that no less than 80,000 tons of copper have been carried into the Bay of Huelva from the Rio Tinto Mines alone since the period of the Roman occupation. Such operations must have been much more common in the earlier geologic ages. M. Dieulefait has argued (*Assoc. Scient. de France*, 1883) that the terrestrial waters have thus supplied many of the mineral substances found in the lodes which traverse stratified rocks.

[2] See R. N. Worth, "The Dartmoor Volcano," *Trans. Plym. Inst.*, 1888–9.

great pressure, so that it had a very high temperature; furthermore, it was saturated with water and acid vapours, as well as with various metallic compounds. It was therefore in a "critical state" of pseudo-fusion, and consequently capable of energetic action on the surrounding rocks.

(10) At periods somewhat later than the granitic intrusions certain fissures were opened in the neighbourhood of the granite, and mostly along lines corresponding with the strike of the stratified rocks. These became filled with fused or pseudo-fused material of a granitoid character, and form the "elvans" which characterise the mining districts.

(11) Later both the granite and the surrounding rocks were extensively fissured, and the fissures, having been partly or entirely filled with new deposits, are now known as lodes, cross-courses, trawns, flucans, gozzans, slides, etc. These fissures were formed and filled at a great many different times, mostly but not exclusively after the formation of the elvans. The main fissures in the slate often, and probably always, extend so far down as to enter and traverse the mineralised granite, while many of the secondary fissures fall into the main fissures at moderate depths.

(12) Most of these later fissures contain deposits of metallic minerals, such as tin, copper, iron, zinc, etc., in some parts of their length or depth. Except in the St. Just district, however, tin has rarely been found in fissures whose courses are nearly north and south.

(13) Some of the lode-fissures have been followed down to depths of half a mile or more, and have still been found to contain mineral substances of value. We have, however, as yet no positive knowledge of the actual depth from surface to which the main fissures extend, either in the slate or in the granite. At any rate they can hardly enter the "region of flow," wherever that may be situated.

(14) In connexion with each system of geoclines there seem to be at least two sets of fissures, viz.: (*a*) A system of "right-

running" fissures whose course is parallel or nearly so to that of the geoclines; (*b*) A system whose course is nearly at right-angles to the foregoing.

Very frequently there is a third set (*c*) forming considerable angles with (*a*), and known as "caunters" or "contras." Of each of these there are, or may be, two sub-systems, α and β, underlying respectively towards or away from the nearest granite.

(15) Although formed and filled at many different times, yet, speaking generally, it may be said that the right-running lodes are older than the caunters, and the caunters older than the cross-courses.

(16) There is no reason to believe that any of these lode-fissures have been formed by anything like an explosive force. On the contrary, it would seem that the *vera causa* in most, if not all, cases has been gravitational force operating during periods of contraction or relaxation of pressure.

(17) Many of the fissures, however produced, have followed foliation, cleavage, jointing, or other planes of weakness which already existed in the rocks; as planes of deposition, or as results of earlier rock-movements.

(18) There are many phenomena which point to the conclusion that the fissures were formed at many different times; also that the metalliferous deposits have been brought into the fissures from without at many different times. There is very frequent evidence of re-opening and of faulting, the movement which took place having been nearly always a "descent of the hanging wall."

(19) On the whole it may be said that the faulting has been least in the case of the caunters, greater in that of the right-running lodes, and greatest in that of the cross-courses; many of these latter show large displacements, extending in some instances to six hundred feet, or even more, so that the cumulative effect amounts to thousands of feet of downthrow as one proceeds from west to east, most of the downthrows being to the eastward.

The successive formation of fissures of these different classes is very fully discussed.

(20) The weight of evidence goes to show that all the ore-material was originally derived from deep-seated sources. That which existed in the most ancient stratified rocks was either derived from the destruction of still more ancient rocks, or was deposited from seas which had been mineralised by springs arising from the depths, or was brought up by volcanoes.

(21) While much of the copper now present in the veins may have been brought up from considerable depths by the basic intrusions, there is reason for believing that the granite is the original source of the greater part of the material now filling the lodes proper and more particularly of the tin.

(22) It seems probable that the tin and other metallic minerals, together with their characteristic associates, were originally distributed pretty evenly throughout the granite masses; that as these cooled the minerals became partly segregated near the outer surface so as to form a mineralised crust, at the same time partly impregnating the neighbouring slates and so forming the "granitic aureole"; when on further cooling fissures were formed in the stratified rocks extending into the granite, such fissures became charged with the tin, copper, and other metallic minerals now found in them, the tin for the most part being deposited in the granite itself or in the killas very near to the granite, the copper somewhat higher up in the fissures, and the zinc and lead still higher up or farther from the granite. From a geological point of view the most important elements thus concentrated in or near the region of the granite junctions are boron and fluorine, mostly in the mineral tourmaline (schorl); economically, the most important is certainly tin, which is often accompanied by tungsten and arsenic.

(23) If the foregoing propositions are accepted it may still be the case that much of the iron oxide, iron and copper sulphide, and oxide of manganese of the Devonian and Carboniferous rocks is pre-granitic in origin. On the other hand, there is very little reason for supposing that there was any tin in the rocks before the granite was intruded. In a sense, therefore, the tin deposits of this region are less ancient than some of the copper

deposits, notwithstanding the fact that in the lodes themselves copper minerals are seen to rest upon cassiterite, while the reverse is seldom the case.

(24) The existence of depth-zones in the lode contents has been well ascertained in many parts of the ore-region. The chief of these are, no doubt, of what may be called primary origin, as indicated in (22). Minor mineral zones, of gozzans, oxidised copper ores, and the like, which have often been of considerable economic importance, are obviously of secondary origin. Furthermore, there appear to be some indications that fissures which extend far into the granite, *i.e.* beyond the depth of half a mile or so, will not continue to yield valuable products in profitable quantities. In other words, a general impoverishment in depth (though not at very shallow depths) is to be expected; hence the great importance of lateral rather than vertical explorations.

(25) The forms and situations of the workable ore-bodies or "rich parts" depend in some degree upon the relations between the strike and dip of the country and the course and underlie of the lode-fissures, and consequently are subject to ascertained or ascertainable laws.

(26) Contact metamorphism as seen in the impregnation of the sedimentary rocks which are in the immediate neighbourhood of the granite, as also the concentration of mineral matters near the surface of the granite itself, was chiefly effected rather by pneumatolysis than by water-circulation at a period when the rocks were subject to great pressure and consequently not fissured. It is to such action that the numerous killas stock-works probably owe their origin, being notable examples of impregnation; the carbonas being equally notable examples of segregation.

(27) The various effects resulting from the circulation of water in downward, lateral, and upward currents which have played such an important part, not only in the formation of workable ore-bodies, but also in effecting pseudomorphic changes in the rocks themselves, are fully discussed, and the "descension,"

"lateral secretion," and "ascension" theories are seen to be mutually related.

(28) In connexion with the circulatory system the effects of variation of temperature and pressure—of chemical interaction of surface-tension—and of the electrical forces, in determining solution and re-deposition, are fully considered and discussed.

(29) The variety of mineral components existing in this region is noticeable—almost all the known elements having been met with except mercury and the metals of the platinum group. The number of minerals found is also very large—Dolcoath alone having supplied more than a hundred distinct species.

(30) In Appendix A some account is given of the china-clay and china-stone deposits which form so important a part of the mineral wealth of the West of England. It is argued that these have been produced in part by the pneumatolitic alteration of certain portions of the granite, and in part by water-circulation in fissures, but scarcely at all by atmospheric influences.

(31) In Appendix B the phenomena of the detrital tin deposits which were once so important are described and discussed in considerable detail. It is concluded that they are for the most part results of the extensive denudation of junction rocks, which were rich in mineral segregations and impregnations and traversed by mineral veins. Cassiterite being heavier than most other mineral substances, and at the same time better able to resist the decomposing forces of nature, is usually found at the bottom of the alluvial deposits and resting upon the solid rock surface without much admixture of other metallic minerals.

In Appendix C a brief outline of the history and statistics of production of each of the more important mines is given, together with a short summary of the production of the district as a whole.

PRACTICAL CONCLUSIONS. Among the more important practical conclusions resulting from this study may be mentioned here the following:—

(*a*) The region, particularly as regards tin, is far from being exhausted.

(*b*) Future explorations should be directed mainly to localities which are near the granite junctions, although important veins containing ores of lead, zinc, iron, and manganese have been found at considerable distances from such junctions. As regards the interior portions of the granite masses, it is obvious, if our general conclusions are accepted, that only in very exceptional cases could one expect to find good deposits therein, since not only the "aureole" but also the "mineralised crust" have long ago been denuded away. On the other hand, wherever in the killas regions there is reason to believe that granite would be met with at moderate depths by sinking, there one might expect to find tin stock-works or payable lodes.

(*c*) In the case of definite lodes, exploration should in future be more in lateral and less in vertical directions than has hitherto been the case. Owing to difficulties of tenure, of water, and of finance, the tendency has hitherto, very naturally, been to follow any rich shoot in a downward direction, while neglecting not only the parallel lodes, but also the lateral exploration of poor parts of the same lode; hence the longitudinal sections of many great mines show the drifts becoming shorter and shorter as depth is attained, until finally they end in a mere sump.

(*d*) It is probable that as greater depths are generally reached the average richness of the ores met with will be lower, necessitating more modern systems of working and on a larger scale, and consequently much larger expenditures of capital, before any important returns can be secured.

(*e*) It is not likely that the capital necessary for such large preliminary designs will be obtainable, unless better lease terms are granted by the "lords." In fact, if the industry is to continue, greater freedom of action will be necessary, with less interference from individual landowners, and with lower scales of royalties, which also must not be exacted during periods of unprofitable expenditure.

I trust I have not wearied you in presenting this outline of a long work, which has only been possible owing to the abundant labours of my predecessor. I have now a pleasant duty to

perform, and that is to present the Bolitho Medal to a very worthy colleague, who has previously done the same for me. At one time the members of our leading Cornish families who took an interest in scientific pursuits were very numerous, as may be readily seen by a glance at the past lists of membership of this and its kindred societies. Of late we have had to count by units rather than by scores. Prominent among those units is a worthy son of a worthy father, our good friend Mr. John Davies Enys. Mr. Enys also interests himself in Biology and Archæology. With these pursuits in the technical sense we have for the moment no concern. But his interest in Geology, Mineralogy, and Mining brings him within the scope of this Society's efforts and recognition. As you know, he has rendered the Society great services as President and otherwise in the past, and I am sure we may with confidence rely upon his further good services in the future. I have now to ask Mr. Enys to accept this Medal as a token of the Society's high appreciation of his services and attainments.

REPORT OF THE COUNCIL

To the Annual General Meeting, October 25th, 1904.

THE Council have the pleasure to report to this the Ninety-first Annual Meeting of the Society that all the property of the Society, including the buildings, as well as the Museum Collections and the Library, are in good order and well cared for.

The several specimens added to the collections during the year are now laid on the table.

As will be seen from the Report of the Librarian, the number of the books and pamphlets in the Library continues to increase and press inconveniently on the available space for shelf room.

It is with most sincere regret that the Council record the death, on the 19th April last, of Sir Clement Le Neve Foster, F.R.S., who was President of this Society for the two years 1900–1 and 1901–2, and was awarded the William Bolitho Gold Medal on the 13th November, 1900.

Sir Clement Foster was elected Curator of this Society in 1865, and actively discharged the duties of that office until 1868, in which year he was engaged in scientific deputations in Egypt and America. He was again elected in 1869, but in the following year he resigned, agreeing with the Council that the duties of the office could only be discharged by a local resident.

He was re-elected to the same office on his return to Cornwall

in 1873, in which year he became a life member of the Society, and again in 1874, 1875, 1876, 1877, 1878, and 1879, when he left the county to take the appointment of H.M. Inspector of Mines in North Wales.

In addition to the useful services rendered to the Society in the discharge of his office in these years, our *Transactions* have been enriched by the following papers from his pen :—

"On Andrewsite." Vol. ix. 163.
"The Tin Deposits of East Wheal Lovell." Vol. ix. 166-176.
"Some Tin Lodes in the St. Agnes District." Vol. ix. 205-219.
"A Rock resembling Luxullianite." Vol. x. 8.
"Balleswidden Mine" (with Capt. T. Rowe). Vol. x. 10-17.
"Notes on the Van Mine." Vol. x. 33-46.
"Cobalt Ore in Flintshire." Vol. x. 107-112.
"Aberllefenny Slate Mine." Vol. x. 169-174.
"An emanation of Carbonic Acid Gas at Foxdale Mine, Isle of Man." Vol. x. 175.
"Native Gold from Leadville, Colorado." Vol. x. 220.

In addition to the reports which he contributed as Curator, and the two addresses which he delivered as President, both of which are still fresh in the memories of the members.

It would be superfluous for the Council to dwell on the high position which Sir Clement Foster occupied in the scientific world, or to remind the members of his great abilities and eminent services to science and the country in general, but the foregoing record suffices to show that this Society has sustained by his death a personal and intimate loss, and has a particular reason to record the regret which all the members feel.

The Council also record with sincere regret the death during the year of Mr. Thomas King, for many years H.M. Inspector of Schools for the County, and a steady supporter of the Society.

The new Geological Survey has been carried on energetically during the year, and the Council hope that it will not be long before the results of the labours of Mr. C. Reid and assistants will be available to the public.

The Council have decided to award the William Bolitho Gold Medal for the year to Mr. J. D. Enys, whose name needs no

introduction, and who has so thoroughly deserved grateful recognition for the public spirit which preserved the Rashleigh Collection of Minerals for the public service of the County.

Mr. Enys has filled the office of President for four years, and the Society is much indebted to him for the unfailing interest he has taken in the affairs of the Society for many years.

The Council recommend the election of Dr. Richard Pearce as President for the next two years.

LIBRARIAN'S REPORT.

1904.

THE Librarian acknowledges with thanks the receipt of publications from the following:—

American Philosophical Society.
—— Academy of Arts and Sciences.
—— Geographical Society.
—— Institute of Mining Engineers.
Australian Association for the advancement of the Sciences.
Belgium. Société Royale Malacologique.
British Association.
Buenos Aires. Museo Nacional.
Buffalo. Society of Natural Sciences.
Canada. Department of the Interior.
——. Geological Survey.
——. Royal Society.
Canadian Institute.
—— Record of Science.
Cape of Good Hope. Department of Agriculture.
Cincinnati. Society of Natural History.
Colorado Scientific Society.
—— College Studies.
Cornwall Royal Polytechnic Society.
Dorpat. Naturforscher Gesellschaft bei der Universitat Jurjew.
Dublin Royal Society.
Elisha Mitchell Scientific Society.
Geological Society.
Geologists' Association.
India. Geological Survey.

Indiana Academy of Science.
—— Department of Geology.
Iowa. Geological Survey.
Japan. College of Science of the Imperial University of Tokyo.
Leicester. Literary and Philosophical Society.
London. Geological Society.
London and West Country Chamber of Mines.
Manchester. Geological Society.
—— Geographical Society.
Maryland. Geological Survey.
Mexico. Instituto Geologico.
Mineralogical Magazine.
Monte Video. Museo Nacional.
Montana University.
Natal. Geological Survey.
New York. Academy of Sciences.
New Zealand. Department of Mines.
New South Wales. Geological Survey.
Normandie. Societe Geologique.
North Carolina. Academy of Sciences.
North of England Institute of Mechanical and Mining Engineers.
Ottawa. Superintendent of Mines.
Peru. Cuerpo des Ingenieros de Minas.
Philadelphia. Academy of Natural Sciences.
Pisa. Societa Toscana.
Plymouth Institution.
Queensland Government.
Rio de Janeiro. Museo Nacional.
Royal Society.
Saxony. Berg und Huttenwesen.
Smithsonian Institution.
South Australian School of Mines.
Sweden. Geological Survey.
United States. Geological Survey.
Upsala.
Uruguay. Museo Nacional de Montevideo.

Vienna. K. K. Geologischen Reichsanstalt.

Victoria. Department of Mines

Western Australia. Geological Survey.

Wisconsin Academy.

Yorkshire Geological and Polytechnic Society.

[*From the Authors.*]

Remarks on the Devonian and Carboniferous Rocks in South Devon and Cornwall. By W. A. E. Ussher, F.G.S.

The Gold Deposits of New Zealand. By Alexander McKay, F.G.S.

Report on the Foraminifera of the Malay Archipelago. By F. W. Millett, F.R.M.S.

On the Iron Ore Deposits in Sydvaranger. By G. Henriksen.

La Géologie au Terrain Houiller du nord de la Belgique. By MM. Lohest, Habet, and Forir.

On a Probable Palæolithic Floor at Prah Sands. By C. Reid, F.R.S.

Eine Skizze der vegetation des Kreisis Njeshin des Govournment Czernigou. By S. Michaglowsky.

West Australian Mining and Metallurgy. By D. Clark, B.C.E.

The Geology of Kingsbridge and Salcombe. By W. A. E. Ussher, F.G.S.

[*Purchased.*]

Palæontographical Society. Vol. lii.

London, Edinburgh, and Dublin Philosophical Magazine.

CURATOR'S REPORT.

DONATIONS TO THE MUSEUM.

By HOWARD FOX, F.G.S.:—

Pteroconus mirus, Group of, from Bedruthan.

" " A very good specimen from Bedruthan.

Collection of Corals and Brachiopods from the northern shores of the Camel Estuary, including *Atrypa reticularis* with perfect structure on a hard nodule from Cant Hill, *Conularia*, etc.

Twenty slides of Foraminifera, from St. Erth clay beds. Presented by F. W. Millett, F.R.M.S.

Candle Clay, containing Microzoa, from Tregonning Hill Presented by T. Clark.

THE WILLIAM BOLITHO GOLD MEDAL,

which is provided for by a fund bequeathed to the Society for the purpose by William Bolitho, of Ponsandane, in 1895, has been awarded annually to the following members:—

1896. R. Etheridge, F.R.S., etc.
1897. Howard Fox, F.G.S.
1898. J. H. Collins, F.G.S.
1899. F. W. Millett, F.R.M.S.
1900. Sir C. Le Neve Foster, F.R.S., etc.
1901. Thomas Clark.
1902. Dr. Richard Pearce, F.G.S.
1903. W. A. E. Ussher, F.G.S.
1904. J. D. Enys, F.G.S.

TREASURER'S STATEMENT, 1904.

Dr. *The Treasurer in Account with the Royal Geological Society of Cornwall.* **Cr.**

Receipts.

October 25th, 1904—	£	s.	d.
To Ordinary Subscriptions	44	2	0
,, Subscription per His Royal Highness the Prince of Wales	20	0	0
,, One Year's Dividend on £1,800 Midland Railway 2½% Debenture Stock, £45 0*s.* 0*d.*, tax, £2 2*s.* 3*d.*	42	17	9
,, Sale of *Transactions*	2	12	6
	£109	12	3
,, Balance due to Treasurer	34	2	2
	£143	14	5

Expenditure.

October 25th, 1904—	£	s.	d.
By Balance from last year's Account	48	2	5
,, Rates and Taxes	0	8	0
,, Curator's Salary	42	17	9
,, *Transactions*, Periodicals, etc.	29	15	3
,, Fire Insurance Premium	2	12	9
,, Coals and Gas	10	3	2
,, Sundry Repairs to Buildings	3	2	2
,, Palæontographical Society	1	1	0
,, Postages, Carriage, Parcels, and petty disbursements	5	11	11
	£143	14	5
,, Balance due to Treasurer	34	2	2

PENZANCE, *October 25th*, 1904.

T. R. BOLITHO, *Treasurer.*

W. BOLITHO GOLD MEDAL ACCOUNT.

Dr.	£	s.	d.	Cr.	£	s.	d.
February 1st, 1904—				October 27th, 1903—			
To Garrard and Co. for 1903 Medal	12	10	0	By Balance	527	9	8
Balance	528	1	8	October 25th, 1904—			
				Interest to April 15th, 1904	13	2	0
	£540	11	8		£540	11	8
				By Balance	528	1	8

LIST OF PAPERS

READ TO AND PUBLISHED BY THE SOCIETY.

1904.

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1. President's Address. By J. H. Collins, F.G.S.
2. Further Notes on the Devonian Rocks and Fossils in the Parish of St. Minver. By Howard Fox, F.G.S.

:THER NOTES ON THE DEVONIAN ROCKS AND FOSSILS IN THE PARISH OF ST. MINVER.

By Howard Fox, F.G.S.

(Read 25th October, 1904.)

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INTRODUCTION.

papers that have appeared in your *Transactions* g the past two years on "Some Coast Sections : Parish of St. Minver" only dealt with sections and north of the village of Rock.

the present paper I propose to refer again to of the sections of the sedimentary rocks on orth coast of the parish which contain organ-

isms, and then to give a description of those exposed on the northern shore of the estuary of the Camel in which during the last year I have obtained an interesting series of fossils. In the determination of these I am indebted to Dr. Henry Woodward, F.R.S., for the description of the Trilobites; to Mr. G. C. Crick, F.G.S., for that of the Cephalopods; and to Dr. F. A. Bather for an elaborate study of a fragmentary Ophiurid. Their respective papers and two plates illustrating the fossils are appended. Further, Dr. C. A. Matley, F.G.S., has examined the Brachiopods, and Dr. G. J. Hinde, F.R.S., has drawn up the list of the Corals and Polyzoa. Dr. J. S. Flett, M.A., has also kindly contributed a report on some microscopic sections of igneous rocks from several localities not included in the paper of Mr. Parkinson (vol. xii. part viii., 1903, pp. 676–82). Mr. W. A. E. Ussher, F.G.S., has also favoured me with his own conclusions as to the age of these rocks.

GRAVEL CAVERNS.

SOUTH-EAST OF PENTIRE POINT.

A silicious conglomerate of small bright-coloured pebbles in a slaty matrix, accompanied by much pyrites, occurs in a series of beds which can be traced running in a westerly direction from the western shore of Pentire Haven, both at the base and near the top of the low cliff. It appears again in the floor of the trench which runs seaward from the faulted cliff called "Tar Cavern" in the six-inch

map. After rounding the Point in a N.W. direction, we meet with it again opposite the most northern of two shingle beaches in front of the caves called the "Gravel Caverns." There are several boulders and some beds of this conglomerate on the foreshore conspicuous at all times, but there are also several other beds which are only visible when storms have removed the shingle and sand which usually conceal them. One of these beds can be traced in the slates westward to low-water mark. There is another bed on a higher horizon, forming the ledge at the base of the cliff on the northern side of these beaches, on which one naturally puts one's right hand when climbing up to continue the walk along the base of the cliffs towards Pentire Point.

These conglomerates and some of the slates in contact with them contain pyritised fossils in their slaty matrix weathered on their silicious surface. In the floor of the "Tar Cavern" trench my friend Mr. W. A. E. Ussher, F.G.S., found a small *Orthoceras*, and in the Gravel Caverns two specimens of *Cardiola retrostriata*, and a small Goniatite, determined by Mr. Crick to belong to the genus *Tornoceras*. The only other recognisable fossils in the conglomerates include a fragment of a branching coral, *Pachypora*, sp., crinoidal joints, and some fragments of fossil wood.

COM BEACH.

The slates of this beach, which is 500 yards west of Com Head on the north coast, contain occasional organic remains, such as corals, crinoidal fragments, etc. A boulder of hard blue slate at the mouth of the cave of the western beach has many fragments of small organisms, among them a piece of a branching *Pachypora*, belonging to a species distinct from that in the gravel conglomerates mentioned above.

EPPHAVEN COVE.

At Epphaven Cove, in Portquin Bay, a mile and half east of Com Beach, Miss Barbara Legg found a fragment of a small Ophiurid or brittle-star, which Dr. F. A. Bather has described as the type of a new genus and species under the name of *Sympterura Minveri* (p. 71, Pl. II.).

The slates of this district also contain numerous spine-like bodies, referred to *Styliola*, casts of crinoid stem-joints, and fragments of other organisms which cannot be identified.

NORTHERN SHORES OF THE CAMEL.

We now pass on to consider the fossiliferous rocks shown in the sections along the northern shores of the estuary of the Camel, which lie to the south and east of Rock, and which extend some six miles in length to Trewornan, about one mile north of Wadebridge, this being the eastern boundary of St. Minver parish.

There does not appear to be a previous record of any special fossils having been observed in this district, but it has yielded to me this autumn some of considerable interest, and in a better state of preservation than most of those obtained south of the Camel.

C. W. Peach, in one of his admirable papers on the "Fossil Organic Remains of the South-East Coast of Cornwall," read before your Society more than sixty years ago, describes finding Lower Devonian Fossils in calcareous slate in immediate contact with a greenstone trap dyke in the Van, on the south side of the Blackhead, Mevagissey Bay.[1]

In the Upper Devonian Fossils of St. Minver the best preserved specimens have been similarly found in slates in close proximity to igneous rocks, or interbedded with them.

Mr. Peach also repeatedly refers to the presence of black nodules in the Southern Cornish Slates which are undoubtedly of organic origin, although the structure has disappeared.

The same observation applies to the St. Minver beds, where, however, some of the nodules show slight structure, while others retain sufficient to enable Mr. G. C. Crick to identify amongst them specimens of *Agoniatites.*

The apparent dip of the slates in this district is seldom trustworthy. It is often impossible to distinguish between bedding and cleavage, and the prevalent strike is therefore difficult to determine.

[1] *Trans. Roy. Geol. Soc. Corn.*, vol. vi. p. 13.

Some of the localities in which the bedding planes and the cleavage planes approximate are mentioned hereafter. There are doubtless numerous anticlines and synclines.

We will commence an examination at Rock, and proceed along the shores to the eastern boundary of the parish. This district may be divided into five sections :—

1. *Rock to Porthilly Point*, occupying about 1,100 yards of coast;
2. *Porthilly Point to Gentle Jane*, 1,200 yards of coast;
3. *Gentle Jane Beach to Cant Cove*, which section we will call *Cant Hill*, 2,000 yards of coast;
4. *Cant Cove to Dinham Mill*, 2,700 yards of coast;
5. *Dinham Mill to Trewornan*, 3,000 yards of coast;

in all, say, about six miles of coast-line.

PORTHILLY COVE.

On leaving Rock we are at once met with a great variety of dip and cleavage. The rocks at the foot of the south side of the sea wall east of the hotel are igneous. The slates under the east end are interbedded with limestone beds inclining to the W.S.W. Within a few yards we find dark slates interbedded with limestone beds, of which the cleavage dip is 25° S.S.W., and the true dip is 58° S.S.W.

A little farther on, the dip of the cleavage planes becomes undulating at low angles, while the bedding, where apparent, is variable and as a rule at a higher angle; in some cases almost vertical.

The slates continue to be interbedded with igneous rocks and limestone beds weathering grey, among which a calcite vein, 12 inches thick, is a conspicuous object. We also notice sheets of sand consolidated by calcareous cement.

The slates in the cliff and foreshore are full in places of minute casts and organisms, among which *Styliola* can be recognised; the loose slates which cover the foreshore also contain good specimens of the same form.

From this to the end of the cove we find blue and brown slates more or less fossiliferous, especially in the neighbourhood of a doleritic igneous rock which has beds of slate and limestone on either side of it. The slate is often spotted with a rusty mineral. The fossils are mostly crinoidal fragments and cup corals (*Zaphrentidæ*, etc.) in poor condition of preservation. Mr. John Parkinson found this igneous rock to be a doleritic camptonite similar to that of "Rock Quarry," etc.[1]

After crossing the stream that enters the end of this cove we pass, providing the tide is sufficiently low, along the foreshore under St. Michael's Church to the southern boundary of the cove marked by another igneous rock mass with outlying exposures on the foreshore, which for the sake of convenience

[1] *Trans. Roy. Geol. Soc. Corn.*, xii. p. 682.

we may call "Porthilly Point." About 100 yards west of the church the axis of a fold in the slates is well seen in the low cliff, and we pass a tunnel, or adit, a little north of the Point. In this district the true bedding can be traced, as in many other places along the cliff, by compact thin bands of slate traversing the cleavage planes.

PORTHILLY POINT TO GENTLE JANE.

In the cliffs south of Porthilly Point we found small black nodules in the slates showing structure suggestive of *Conularia*, and a foot under the soil on the top of the cliffs there are rows of cockle shells, the relics of former feastings. After passing a second exposure of igneous rock, we soon reach a place where the low cliffs for some 150 yards have from time to time been quarried for slates, and the foreshore is covered with the débris. At the northern end of this range we may find on splitting these loose slates an occasional cast of a brachiopod, bivalve, or *Styliola*, with crinoidal fragments and groups of *Pleurodictyum*. These quarries can be reached at any state of the tide through a field adjoining the churchyard. Four conspicuous grassy mounds in this field are probably due to the slower erosion of underlying igneous rocks.

As we continue our southward walk along these quarries the slate becomes increasingly full of fossils, and *Pleurodictyum* becomes so plentiful that we found four groups weathered out on the surface of

a single loose slab of slate, 3 feet long by 2½ broad. Another specimen was in an exceptionally good state of preservation. Fragments of *Conularia*, cup-corals, crinoids, and other organisms are numerous, but they are, for the most part, in a bad state of preservation.

We may call this the *Pleurodictyum Area.*

A little farther south the cliffs consist of igneous rock for some 32 yards, viz. 15 yards west and 17 yards east of the place where the third hedge from Porthilly Point abuts on the cliff.

Several beds of this igneous rock, 10–15 inches thick, can be traced in the slates on the foreshore. The black nodules which characterise some of the slate in this neighbourhood suggest *Goniatites*, but we failed to obtain undoubted structure in any of them.

About 300 yards west of Gentle Jane Beach two small trilobites were found in blue slate, *in situ*, on the foreshore.

"CANT HILL."

GENTLE JANE BEACH TO CANT COVE.

This beach, like most of the foreshore from Porthilly Point, is composed of worn fragments of blue slate, with very little admixture of quartz or sand of any description. It lies at the western foot of a long flat-topped eminence, 247 feet above sea-level, mostly composed of volcanic rock, which is named "Cant Hill" on the ordnance map. This igneous rock is much weathered and decomposed, and Mr.

eastern side of this rock a good specimen of *Fenestella* or *Polypora* was secured, and within twenty yards west of it another trilobite was obtained in a blue slate *in situ* inclining N.E. in the foreshore.

We propose calling this prolific section of the cliff the *Trilobite Area.*

From this to the entrance to Cant Cove the foreshore becomes more or less covered with small fragments of volcanic rock, much altered and decomposed, tuffs both fine and coarse-grained, the latter predominating, ash, and near the eastern end we meet with fine-grained porphyritic basic rock which clinks under the hammer (No. 717 of Dr. Flett's notes).

The "old quarry" marked in the six-inch map can be reached by climbing under and through the brushwood which covers the talus and fallen overburden, from a place almost opposite an isolated block of tuff (No. 716 of Dr. Flett's notes, p. 56) on the foreshore close to high-water mark. The face of the quarry, which can be traced along the top of this cliff, is all composed of *Schalstein,* which apparently forms the greater part of Cant Hill. One hundred yards east of this isolated block is a group of similar large blocks of tuff, and 80 yards still further east three others, all close to the base of the cliff.

The most fossiliferous slates were found in this neighbourhood, some *in situ,* others in loose slabs at the base of the cliff. A perfect specimen of *Atrypa*

reticularis, Linn., was found by my daughter, partially exposed on a hard basic nodule.

Mr. Clement Reid, F.R.S., suggests that its perfect condition is owing to chalcedony having replaced the shell.

Some decomposed rusty spotted slates were so full of friable internal and external casts of fossils that it was impossible to split them without breaking many of the fossils.

In addition to the genera mentioned above as occurring in the tract of foreshore included in the term "Cant Hill," the following are also represented: *Petraia*, *Zaphrentis*, *Cyathophyllum*, *Amplexus*, *Favosites*, *Alveolites*, *Pleurodictyum*, *Monticulipora*, *Fenestella*, *Polypora*, *Phyllopora*, *Atrypa*, *Spirifer*, *Pentamerus*, *Rhynchonella*, *Orthothetes*, and *Conularia*. Crinoidal remains are also numerous, but they cannot be assigned to any particular genus.

Beyond this range of igneous foreshore, below an old cart-road, there are some fossiliferous slates *in situ*. Brownish slate, followed by blue slate with *Pleurodictyum*, etc., continue to the entrance to Cant Cove. The slates on the western side of this cove incline S. near the entrance, then S.S.W., and at the upper end W. 20°.

CANT COVE TO DINHAM MILL CREEK.

The mud of Cant Cove is so soft at times that it is difficult to skirt round and reach the eastern side of the cove without discomfort. As we emerge from it and round the point on the east, we find

slates inclining from E.N.E. to due E. about 25°, and we see, near a cart-road gate, pale grey slate dipping S. of E. full of cup-corals. We obtained here, above high-water mark, an *Orthoceras*, 8 inches long (Pl. I., Figs. 6*a*, 6*b*), which was weathered out very conspicuously on the pale slate, so much so as to imply that no fossil-hunter had visited this place.

We did not in the whole parish notice a single scar indicative of a fossil having been chiselled out or removed.

East of this gate, a bed from 3 to 4 feet thick of pale decomposed, much-sheared, rust-spotted igneous rock, with dark ferruginous bands and lenticles in it, is seen near the base of the cliff, with indurated slate above and below it, in which fossils occur.

Further east the inclination of the slates alters from S. of E. to W.N.W., and within 50 yards it is again east. A small beach marks the change of the apparent cleavage from W. to E.

Beyond this, at the east end of a copse some 100 yards long, a quartz vein or dyke or fault fissure, 5 feet thick, runs in a northerly direction to the top of the cliff, some 20 to 25 feet high, dipping west and showing quartz breccia in places. The neighbouring slates show numerous small synclines and anticlines.

After passing some igneous boulders on the foreshore and a small cave, we reach the débris of an old slate quarry. The quarry is overgrown, and has some large specimens of *Asplenium ruta muraria* and *A. Trichomanes* in its inner wall.

After this we find bluish slate inclining W.S.W. Two intrusive beds of greenstone are seen, 3 to 4 feet thick.

A bed of blue slate in this region yielded a small specimen in a bulged form, which, on being broken open by the fingers, revealed the most perfect little Trilobite we have met with in Cornish rocks. It has been identified by Dr. H. Woodward as *Phacops granulatus*, Münster (p. 60, Pl. I., Fig. 3).

The bedding and cleavage planes in some portions of this district appear to be coincident.

A gate leading to a cart-road up the field marks a local change of the cleavage dip, viz. from S.S.W. to N.N.W.

Light brown and grey slates inclining S.E. show corals, *Styliola*, *Orthoceras*, etc., followed by slates holding crinoidal fragments. One *Orthoceras* was 3 inches long and 1 inch wide at the top.

The entrance to Dinham Mill Creek is marked by numerous blocks and masses of much-weathered igneous rock *in situ*, and the foreshore is strewed with fragments of the same, while a quarry 100 yards inland gives a perpendicular exposure of some 60 feet of this rock in a very fresh and unaltered state. Dr. Flett has described a microscopic section (No. 718) of this rock (p. 57). It is quarried for road metal.

In September the muddy foreshore of the northern end of this creek is covered, to the extent of several acres, with a dense forest of the beautifully jointed, succulent, leafless, horn-like *Salicornia herbacea* or

Glasswort, so called from its abundance of soda causing it to be used in the manufacture of glass.[1]

The slates on the west side of Dinham Mill Creek contain *Styliola*, and they incline to the south until we reach the end where the cart-road crosses the stream over a bridge. Here the apparent dip of the slates is to the north, and they are interbedded with several beds of blue limestone, weathering brown, from one foot in thickness and upwards. De la Beche colours this limestone in the Survey Map.

DINHAM CREEK TO TREWORNAN.

Instead of skirting this creek it is possible to reach the eastern shore near its entrance by walking along an embankment across its mouth, and stepping over the stream, where in former times a sluice-gate was connected with a water-wheel that worked the "Bone Mill" indicated on the six-inch map. If we take this route we land on igneous rocks, not marked on the Survey Maps, similar in character to those on the western side of the entrance No. 718. These igneous rocks continue for some distance round the corner.

The junction of the slates with the igneous rock runs along the base of the low cliffs in one place, the rocks in the foreshore being sedimentary. The igneous rock is a pale greenish grey, mottled with darker patches of the same colour. One junction is marked by a tunnel, or adit, excavated by miners in old days on a mineral lode.

[1] John's *Flowers of the Field.*

Several specimens of *Orthoceras* were obtained in grey slate from this region. An intrusive bed of much-altered, buff-coloured, igneous rock occupies about 30 feet of the cliff where the coast-line runs north and south. On its southern boundary the slate in contact with it is somewhat indurated, greenish grey in colour, and contains *Styliola*, etc. On its northern boundary we find soft, fine-textured, compact-looking, yellow-buff slates or shales, weathering a greenish colour, which contain numerous small fossils including *Styliola*.

Continuing our walk we pass a salt-marsh, 200 yards long, and notice that the grey slates, inclining at a low angle, become much jointed. The joints are parallel and traverse the rock horizontally and perpendicularly; they are marked by quartz and dark films apparently of limonite. Some nodules of harder material, not effervescing in cold acid, are enclosed in the rock. The same structure of numerous joints at right angles with ferruginous films and quartz veins mark the slates near the variegated slates north of Rock. A sloping embankment of slates, over 40 yards in length, acts as a dam against the water to a low meadow, at the upper end of which, close to the carriage-drive through the wood to Dinham House, is an old quarry of the purple and green slates.

A beach succeeds the embankment, and marks the reappearance in the cliffs and foreshore of the variegated slates which monopolise a considerable portion of the shore-line to Trewornan. These

purple and green slates have not as yet yielded any fossils, but it is probable that further minute examination will prove that they contain *Styliola*, *Tentaculites*, and *Entomis*. Mr. Ussher has recently found *Styliola* and *Tentaculites* in the variegated slates of the cliffs of Butter Cove, south-west of Stepper Point, south of the Camel.

Three hundred yards east of the slate embankment, in the neighbourhood of the place where the first hedge abuts on the low cliff, we find darkish grey slates with bedding at right angles to the low cleavage dip, causing the rock to break into rectangular prisms or splinters. The bedding planes are indicated by the grain of the rock, occasional stripes and colour bands of slightly differentiated material, and by pyritised fossils, amongst which *Orthoceras* was the only determinable form obtained, although indications of *Bactrites* and small *Goniatites* were present. This type of rock passes into or under the purple and green slates which occur from Trewornan westward. Further east a quarry of darkish grey slate, with bedding planes crossing the cleavage indicated by streaks of more ferruginous or decomposed material, is seen within 150 yards of the highroad leading from Trewornan westward.

LIST OF FOSSILS FROM ST. MINVER.

The following list of the fossils obtained from the various localities mentioned above, has been drawn up with the object of facilitating a comparison with

those from the Devonian rock series in other areas in Cornwall and elsewhere.

ACTINOZOA.

Petraia spp. Casts of small cup-corals, probably representing two or more species. Common at Cant Hill, east of Cant Cove.

Zaphrentis sp. Depressed conical; at summit 20 mm. wide; 20 principal septa; well-marked fossula. Cant Hill.

Amplexus (?) sp. Compound, branching, the branches diverge from a common stock, about 10–15 mm. in diameter and about 150 mm. in length; septa about 40, their interior characters not shown. Cant Hill.

Cyathophyllum sp. Cylindrical, 5–6 mm. in diameter, about 36 septa. Rare. Cant Hill.

Favosites sp. A small fragment on a slab with *Atrypa reticularis.* Cant Hill.

Alveolites sp. Plate-like growths, some measuring 70 mm. by 50 mm.; walls replaced by rusty material; corallites about 0·5 mm. in width. Common. Cant Hill.

Pachypora sp. *a.* Branching form; the branches about 5 mm. in diameter, and the corallites about 0·5 mm. wide. West of Com Head.

Pachypora sp. *b.* Fragment of a branching specimen, the branches 10 mm. in diameter, corallites round or oval, 0·8 mm. wide. Gravel cavern conglomerate, south of Pentire Point.

Pleurodictyum sp. The same forms as those from Constantine Bay, Porthcothan Cove, and other localities, described in *Trans. R. Geol. Soc. Corn.*, vol. xii. (1900), p. 348, Pl. XVI. Fig. 11, and *Geol. Mag.*, dec. 4, vol. vii. (1900), p. 151, Pl. VII. Fig. 11. East of Porthilly and Cant Hill. Common.

Ophiuridea and Crinoidea.

Sympterura Minveri, Bather. (See accompanying paper.) Epphaven.

Crinoidea. Stem-joints, usually as casts. Epphaven; west of Com Head; south of Pentire Head, in conglomerate; Porthilly Cove; south of Porthilly Point; Cant Hill; east of Cant Cove. Common.

Trilobita.

Described by Dr. H. Woodward. (See accompanying paper.)

Phacops latifrons, Bronn. Cant Hill. Common.

" *granulatus*, Münster. Cant Hill; east of Cant Cove. Common.

" (*Cryphæus*) *punctatus*, Steininger. Cant Hill.

" (*Trimerocephalus*) *lævis* (?), Münster. Cant Hill.

Polyzoa.

Monticulipora (*Monotrypa*) sp. A small fragment, encrusting, cells about 0·25 mm. broad. Cant Hill.

Fenestella, sp. (*a*). Polyzoary fan-shaped, branches straight, closely set, 0·5 mm. in width, fenestrules oval, 0·5 mm. in length, 2–3 zoœcia between each dissepiment, apertures prominent and thickened. Cant Hill.

Fenestella, sp. (*b*). Only a small part of the upper face shown. Branches narrow, 0·3 mm. in width, keel prominent, fenestrules sub-angular, about 0·8 mm. in length, 2–3 cells between each dissepiment. Cant Hill.

Polypora sp. Fragment. Branches 0·5–0·7 mm. broad, fenestrules oval, 1 mm. long by 0·5 mm. wide; 3–4 rows of cells. East of Cant Cove.

Phyllopora sp. Fragment. Branches inosculating, 0·5–0·8 mm. in width, 3–4 rows of cells, alternating, fenestrules elongate, irregular. Cant Hill.

BRACHIOPODA.

The Brachiopods have been kindly examined by Dr. C. A. Matley, who reports that, owing to the fact that many of the specimens are only casts, and these often crushed and distorted, their exact identification is very difficult, and the names given to them should, therefore, with some exceptions, be considered as approximations rather than certainties.

Orthothetes crenistria (?), Phill. Fragments only. Cant Hill.

Orthothetes (?). Cast of interior; the characters are peculiar and the genus cannot satisfactorily be defined. Cant Hill.

Atrypa reticularis, Linn. A single specimen, well preserved. Cant Hill.

Atrypa cf. *desquamata*, Sowerby. Dr. Matley states: "I am doubtful, as there are some peculiar ridges in the interior of both valves (shown in the internal casts), which I have not met with before in this genus." This is the commonest form; ten specimens were obtained, the majority are casts. Cant Hill.

Spirifer sp. The nearest species to this seems to be *S. cultrijugata*, Roemer, but this appears to be quite distinct. Cant Hill.

Spirifer sp., cf. *S. speciosa*, Schl. A single specimen. Cant Hill.

Pentamerus (? *Gypidula*) *brevirostris*, Phill. An internal cast. Cant Hill.

Rynchonella (*Camarotœchia*) *laticosta*, Phill., ? var. There are only four ribs on the fold. An internal cast. Cant Hill.

LAMELLIBRANCHIATA.

Cardiola retrostriata, von Buch. Pyritised casts. Gravel caverns conglomerate. South of Pentire Point.

Pteropoda.

Styliola sp. Epphaven, Porthilly Cove, west and east of Dinham Creek.

Conularia subparallela, Sandberger. Cant Hill.

" sp., cf. *C deflexicosta*, Sandberger. Porthilly, Cant Hill.

Cephalopoda.

Described by Mr. G. C. Crick. (See accompanying paper.)

Orthoceras cf. *Hercynicum*, Kayser. East of Cant Cove.

" cf. *commutatum*, Giebel. Cant Hill.

" *nassoviense*, Foord. East of Dinham Creek, Trewornan.

" cf. *O. rapæforme*, Roem., and *O. subconicum*, Roem. East of Dinham Creek.

" *gracile*, Blum. Trewornan.

" or *Bactrites*. Conglomerate. Gravel Caverns, south of Pentire Point.

Bactrites sp. Trewornan.

Cophinoceras sp. Cant Hill.

Phragmoceras (?) sp. Cant Hill.

Tornoceras sp. Conglomerate. Gravel Caverns.

Agoniatites sp. Cant Hill.

Summary.

Although the specific characters of many of the fossils in the above list cannot be recognised owing to their imperfect preservation, there appears to be sufficient evidence to justify the conclusion that whilst the Gravel Caverns conglomerate and the slate rocks forming the banks of the north shore of the Camel estuary in the Porthilly and Dinham Creek districts are Upper Devonian, those in the intermediate and more southern region of Cant Hill may be Middle Devonian in age.

IGNEOUS ROCKS.

In the former paper on "Some Coast Sections in the Parish of St. Minver" the petrological notes on the rocks were kindly made by Mr. John Parkinson, F.G.S., of Cambridge, who visited the various localities with me, and they appeared at the end of the paper.[1]

As Mr. Parkinson is engaged in South Africa I have had to seek elsewhere for assistance, and have been fortunate enough to receive the kind help of Dr. Flett, of the Geological Survey, who examined and described specimens from five localities, viz.:—

Specimen, No. 715, from the basaltic cliff north-west of Pentire Point.

No. 724, from the middle one of three contiguous beds, or dykes, on the south-west foreshore of Cant Hill.

No. 716, from the main portion and middle of Cant Hill.

No. 717, from the south-east foreshore of Cant Hill.

No. 718, from Dinham Quarry, west of the entrance to Dinham Creek.

NOTES BY JOHN SMITH FLETT, M.A., D.Sc.

715. From Pentire Point Cliff, St. Minver.

A very vesicular andesite or basalt. The numerous vesicles are well rounded and are occupied by calcite and chlorite. The rock contains small porphyritic plagioclase felspars, which have an indistinct fluidal arrangement. They lie

[1] *Trans. Roy. Geol. Soc. Corn.*, vol. xii. pp. 676–82.

in an exceedingly fine-grained matrix, with small microliths of felspar in a dark material which was probably originally in part glassy. Of the ferro-magnesian minerals none are fresh, but all are represented by obscure pseudomorphs of chlorite and similar substances. Probably the rock contained no olivine and belongs to the augite andesites or andesitic basalts.

724. The Middle Bed of Three contiguous in Foreshore South-east of Gentle Jane, Cant Hill.

A fine-grained, greyish green rock weathering brown. It consists of small prisms of weathered felspar, much of which is probably orthoclase, scales of brown biotite and calcite pseudomorphs, after olivine or augite. There can be little doubt that the rock belongs to the minettes, though it has much less biotite than is usual in this group, and is badly decomposed. Its minerals and structure have many of the peculiarities usually seen in the lamprophyres. There is much disseminated calcite, and secondary quartz appears in some of the pseudomorphs. Iron oxides and apatite are present as accessories.

716. Cant Hill Quarry.

Apparently a tuff, but very thoroughly decomposed. The hand specimens show the clastic character of the rock. In the slide there are large and small fragments of felspar, partly fresh, lying in a matrix of carbonates, chlorite, and other secondary products, including a little quartz. The rock contains dark, highly vesicular areas which are probably volcanic lapilli; they are often flattened or drawn out as if slightly crushed.

717. From Foreshore South-east End of Cant Hill.

A fine-grained rock, similar to 724, belonging, apparently, to the same rock mass.

718. Dinham Quarry.

This is a green, moderately coarse-grained ophitic diabase. Its felspars are in fairly good preservation and show their characteristic twinning, but the augite has all decomposed into a brownish, semi-opaque mixture of carbonates, chlorite, etc. The ophitic structure, however, is very clearly seen, and the rock has apparently not suffered from shearing to any great extent. Whether olivine was originally present or not is doubtful. The principal accessories are iron oxides, decomposing to leucoxene and apatite.

NOTES ON A SERIES OF TRILOBITES OBTAINED BY MR. HOWARD FOX, F.G.S., FROM THE DEVONIAN OF CANT HILL, ST. MINVER, CORNWALL.

By Henry Woodward, LL.D., F.R.S., F.G.S.

(Plate I. Figs. 1–5.)

In September of last year I received from Mr. Howard Fox, F.G.S., of Falmouth, nine specimens of Trilobites for the purpose of determination and description. They are all more or less fragmentary, and distorted by slaty cleavage, as is usually the case with fossils from these Devonian Slates of Cornwall and Devon, reminding one of the distorted Trilobites and Starfishes from the Lower Devonian Slates of Bundenbach, Germany.

I subjoin a list of the specimens received and my notes

thereon, which I hope may prove acceptable to my friends in Cornwall:—

1.	*Phacops latifrons*, Bronn.	Cant Hill,	St. Minver,	North Cornwall.	
2.	,, (*latifrons*?)	,,	,,	,,	,,
3*a*, *b*.	,, *granulatus*, Münster.	E. of Cant Cove,	north shore,	N. Cornwall.	
4.	,, ,, ,,	Cant Hill	St. Minver	,,	
5.	,, ,,	,,	,,	,,	
6.	,, (*latifrons*?)	,,	,,	,,	
7.	,, *punctatus*, Steininger	,,	,,	,,	
8.	,, *lævis* (?), Münster	,,	,,	,,	
9.	,, *latifrons*, Bronn	,,	,,	,,	

1. PHACOPS LATIFRONS, Bronn. (Pl. I. Figs. 1*a*, 1*b*, 2?)

Calymene latifrons, Bronn, 1825. Leonhard's Zeitschr. f. d. Mineral., p. 317, t. ii. Figs. 1–8.

Phacops latifrons, Sandberger, 1850. Verstein. Rheinisch. Schichtensyst. Nassau, t. i. Fig. 7.

Phacops latifrons, Salter, 1864. Mon. Pal. Soc., pt. 1, p. 18, Pl. I. Figs. 9–16.

I have referred Nos. 1, 2, 6, and 9 of Mr. Howard Fox's specimens to *Phacops latifrons*, Bronn, which is one of the most characteristic forms of Devonian Trilobites, and is recorded by writers on this formation from Cornwall, Devon, the Eifel, in Germany, and elsewhere.

No. 1 is a rolled-up and very much compressed specimen drawn on Pl. I. Fig. 1*a*, in profile; the same specimen being also shown from the underside in Fig. 1*b*. Fig. 1*a* exhibits the right cheek or glabella, and the large compound eye, which is very prominent in this species. The surface of the glabella (which in *P. latifrons* is covered with coarse tubercles) is completely obliterated in this specimen by the compression which the fossil has undergone in the matrix. The angle of the cheek is bluntly rounded off and not produced into a genal spine, the border is rounded and slightly elevated. The visual surface of the eye forms a raised crescent, 9 mm. above the cheek border, with a length of 18 mm. along its outer curved surface. It shows upwards of twelve rows of facets, each row having from five to six distinct prominent rounded lenses upon its surface. The compressed body and head are 35 mm. in thickness and 50 mm. long in profile in their present folded-up state.

Fig. 1*b* shows the flattened-out thoracico-abdominal

segments and a part of the pygidium seen from below. The most anterior segments are seen in the profile view, where they unite with the head-shield (Fig. 1*a*); the others in Fig. 1*b*. About ten or eleven free segments can be counted altogether. The ends of the pleuræ are recurved and rounded. A part of the pygidium is exposed, but the rest is buried in the matrix. There is a trace of a single row of three or four tubercles upon the axis of some of the free thoracic segments. The body-segments are 58 mm. broad by 51 mm. long.

No. 2 specimen (see Pl. I. Fig. 2) consists of a pygidium accompanied by five or six displaced thoracic segments. The pygidium is much flattened. It measures 52 mm. in breadth by 36 mm. in length. The axis is composed of about ten or eleven coalesced segments, and is 14 mm. broad at the proximal end (where it united with the free body segments), diminishing to 6 mm. near the blunted free border, which is quite flattened out by pressure. Indications of about six coalesced pleuræ mark the lateral portion of the pygidium; the axis and pleuræ are sparsely ornamented by a single row of small tubercles on each segment. The general rounded form of the pygidium is marred by the extreme compression to which it has been subjected.

On No. 6 (marked doubtfully as *Ph. latifrons*?) are two badly preserved specimens of Trilobites, each showing the head and body rings on the edges of the cleavage-planes (which are stronger than those of the original bedding); both specimens are stained red with peroxide of iron. Except in general resemblance, they are too obscure for accurate determination. Locality as before stated, Cant Hill, St. Minver.

No. 9 exhibits parts of several obscure organisms, preserved on the service of a small slab, some of which appear to be crinoidal, but one is the eye of a Trilobite, and may be referred to *Ph. latifrons*. This species is recorded from the Lower Devonian, Hope and Barton, South Devon;

near Liskeard and Totnes in slates with *Pleurodictyum problematicum.* Middle Devonian, Newton Bushel; Upper Devonian, Barnstaple, Pilton, Yealm Bridge, Launceston. Mr. Howard Fox's specimens are labelled from Cant Hill, St. Minver, on the northern banks of the Camel Estuary.

2. PHACOPS GRANULATUS, Münster. (Pl. I. Figs. 3, 4.)

Calymene granulata, Münster, 1842. Beiträge, Heft 5, t. v. Fig. 3.
,, ,, Phillips, 1841. Pal. Foss., Fig. 248 (excl. Figs. *m, n, o, p*).
Phacops granulatus, Salter, 1864. Mon. Pal. Soc., pt. i. p. 18, Pl. I. Figs. 1–4.

This species is recorded by Salter from the Upper Devonian of Petherwin, Cornwall. Although so small (Pl. I. Fig. 3) it is the best preserved and most interesting of Mr. Fox's specimens. It consists of an intaglio and relievo of a small Trilobite (represented twice the natural size in our Plate), measuring 24 mm. long by 12 mm. broad (originally broader, but compressed by slaty cleavage), and resting on the edges of the cleavage planes and parallel with them, which accounts for its having escaped even greater distortion.

McCoy originally described it in 1851 in his *Synopsis of Woodwardian Fossils*, p. 177. Salter defines it as "General form broad-oval. Head semicircular, very convex, covered with granules. [Owing to the absence of the tests the ornaments of tubercles on the glabella cannot be seen in Mr. Fox's specimen, but traces of these can be detected in the intaglio.] The sides (cheeks) much bent downwards. Glabella fully half the width of the head, very tumid, slightly pointed in front, and overhanging the front margin. Its greatest width exceeds its length, even including the neck-segments; a small basal lobe, with a tubercle on each side, but no glabellal furrows visible. Cheeks moderate [genal border rounded posteriorly], with a strong border. Eyes large, prominent, with few, about thirty-six, lenses, five in a row" (after McCoy). We may add to this:—Thorax consisting of eleven well-defined free-segments; axis strongly arched, semi-cylindrical, with a deep furrow separating it from the pleuræ; pleuræ

strongly recurved, rounded, and somewhat expanded at their extremities. Pygidium semicircular, small, convex, surface somewhat smooth, axis well marked, but divisions of pleuræ only faintly indicated.

Measurements: length of head 7 mm., of eye 4 mm., of thorax 12 mm., of pygidium 5 mm.; breadth of axis of body 3 mm. Mr. Howard Fox's original specimen is from east of Cant Cove, St. Minver.

No. 4. This specimen (Pl. I. Fig. 4) no doubt belongs also to the same species as No. 3. It gives a side view of another example, in which, however, the head is partially wanting, but the crushed glabella and the left eye can be detected.

Total length 24 mm. Head 6 mm. long; length of (11) thoracic segments 12 mm.; pygidium 6 mm. Breadth of exposed axis and left pleuræ 8 mm (broadened by pressure). The form of the pleuræ with their rounded, recurved, and expanded extremities is well seen in Fig. 4. This specimen also comes from the Devonian of Cant Hill, St. Minver.

No. 5. This example is not figured. It is similar in condition to No. 4, but is *less* well preserved. All the thoracic segments seem present; the head, however, is wanting (or represented only by the projecting eye); the pygidium is also absent. Length 15 mm. Same locality as preceding specimen.

3. PHACOPS (CRYPHÆUS) PUNCTATUS, Steininger. (Pl. I. Fig. 5.)

Olenus punctatus, Steininger, 1833. Mém. Soc. Géol. Fr., vol. i. p. 356, Pl. XXII.

Phacops punctatus, Salter, 1864. Mon. Pal. Soc., p. 59, Pl. I. Figs 17–19 (and woodcut, p. 59).

This specimen is marked No. 7 in Mr. Howard Fox's collection, and like the others is from Cant Hill, St. Minver. It consists of the profile of a head of a trilobite showing the free-cheek and compound facetted eye. The margin of the free-cheek has a strong ridge along it, and, although so imperfect a fragment, I am inclined to refer it to *Phacops punctatus*, Steininger. The surface of the shield is punctate,

the head margin is produced in front of the glabella; the posterior angle of the free-cheek, though not complete, shows that it was originally prolonged backwards into a genal spine. Length of fragment 15 mm., length of visual surface of eye 5 mm.

Mr. Salter, in 1864, records imperfect specimens of this species as having been found in the Middle and Lower Devonian of Torquay, South Devon, and from the slates of Liskeard, Cornwall, and he remarks: "It is certain that a very beautiful Trilobite has yet to be found in Cornwall and S. Devon, and collectors should look carefully for it" (Pal. Soc. Mon., p. 60). We have now to add the locality of St. Minver.

No. 8 consists of an imperfect series of nine thoracic segments, and a trace of head and pygidium from Cant Hill. The free extremities of the pleuræ are less curved and less expanded than in *Ph. latifrons* or in *Ph. granulatus*, and the pygidium appears to be more narrow and elongated, but this may be due to distortion in the rock. I do not propose to determine this specimen specifically, but it may be a distorted fragment of *Phacops* (*Trimerocephalus*) *lævis*, which has been obtained both in North and South Devon and at Mudstone Bay, etc.

EXPLANATION OF FIGURES OF TRILOBITES ON PLATE I.

FIG. 1*a*.—Profile of *Phacops latifrons*, Bronn. Devonian: Cant Hill, St. Minver, Cornwall. × ⅓.

,, 1*b*.—Under side of same specimen. Nat. size.

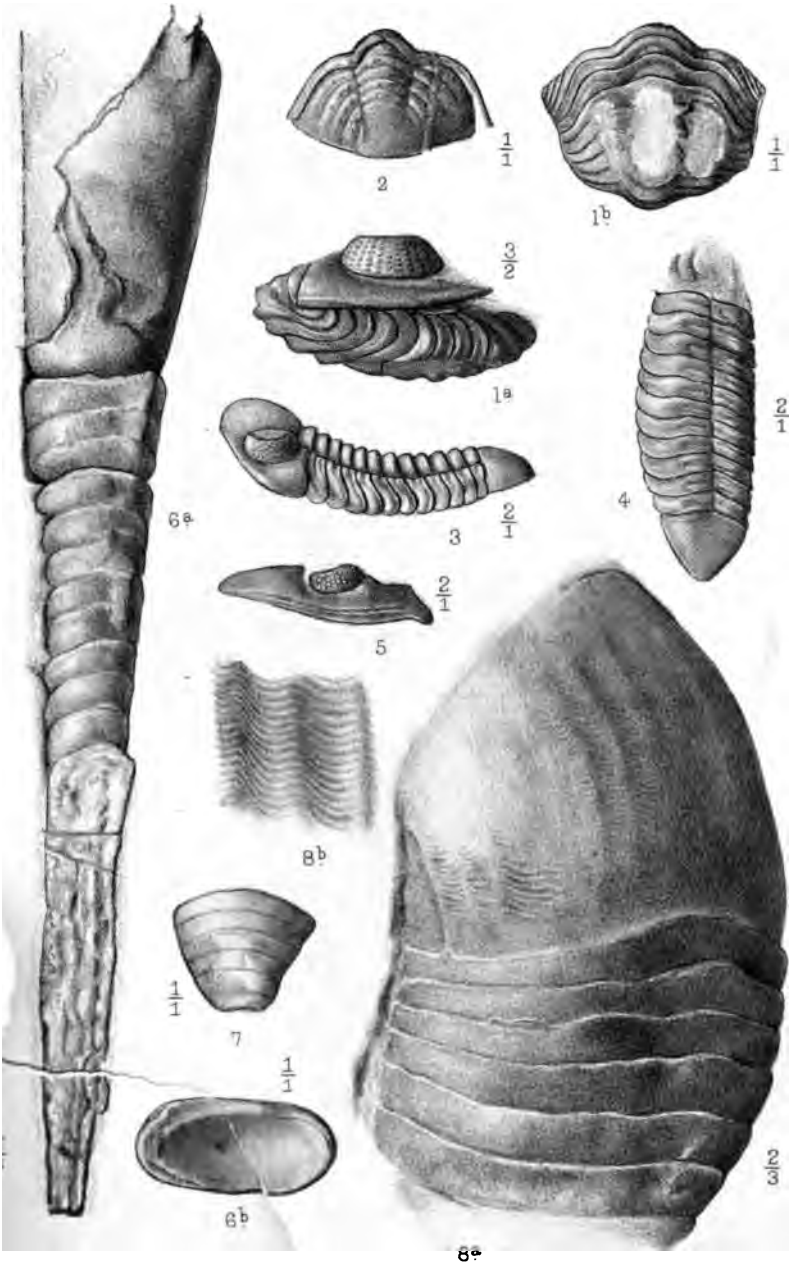
,, 2.—*Ph. latifrons* (?). Pygidium. Devonian: Cant Hill, St. Minver, Cornwall. Nat. size.

,, 3.—*Ph. granulatus*, Münster. Profile of a nearly perfect specimen from same formation, east of Cant Cove, St. Minver. × 2.

,, 4.—*Ph. granulatus*, Münster. A less perfect specimen, showing thoracic segments, imperfect head and pygidium. Same formation, Cant Hill, St. Minver. × 2.

,, 5.—*Ph. punctatus*, Steininger. An imperfect cheek, with eye. × 2.

(For explanation of Figs. 6–8, Pl. I., see end of Mr. G. C. Crick's paper.)



G.M. Woodward del et lith. West, Newman imp.

Devonian Cephalopods and Trilobites from Cornwall.

ON SOME FOSSIL CEPHALOPODA FROM NORTH CORNWALL COLLECTED BY MR. HOWARD FOX, F.G.S.

By G. C. CRICK, F.G.S., of the British Museum (Natural History).

(Plate I. Figs. 6–8.)

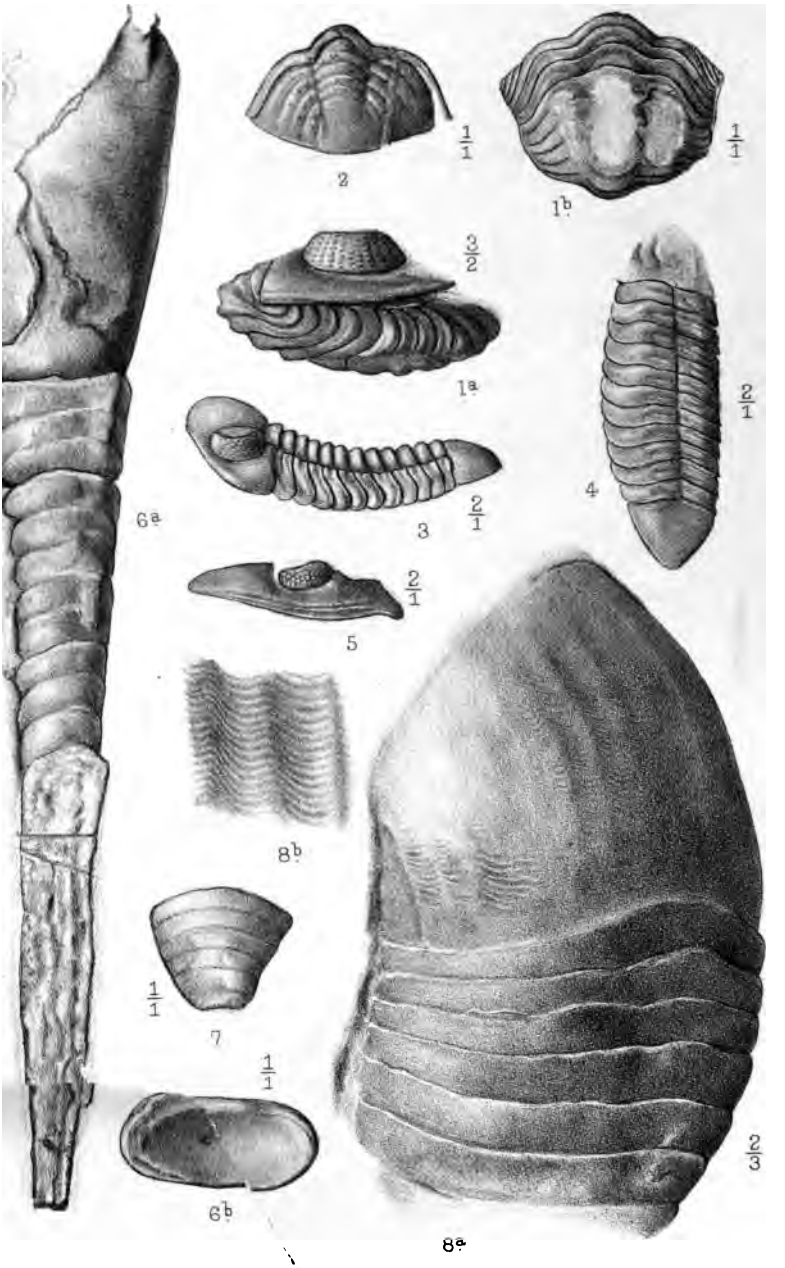
THE following descriptions are based upon fossils sent to me for determination by Mr. Howard Fox, F.G.S. Excepting the specimen which is compared with *Orthoceras hercynicum* and is marked "E. of Cant Cove," the fossils are from Cant Hill, St. Minver, N. Cornwall.

At the end of the descriptions are added notes upon some very imperfect fossils which Mr. Fox has collected from other localities in St. Minver.

ORTHOCERAS cf. HERCYNICUM, E. Kayser. (Pl. I. Figs. 6*a*, 6*b*.)

Orthoceras hercynicum, E. Kayser. Abhandl. zur geolog. Specialkarte v. Preussen, etc., Bd. ii. Heft 4 (1878), p. 72, Pl. X. Figs. 7, 8, 11; Pl. XI. Fig. 3 (?).

Among the specimens submitted to me by Mr. Howard Fox there are several examples of the genus *Orthoceras*. The most nearly perfect specimen is represented in Pl. I. Figs. 6*a*, 6*b*. It is a crushed internal cast about 200 mm. in length, of which the body-chamber occupies about 55 mm. The rate of tapering is about 1 in 5, the greatest width at the aperture being about 40 mm., and at the last septum about 28 mm. In its crushed condition the depth of the chambers is about one-third of their width. The siphuncle is slightly excentric (see Fig. 6*b*). Parallel to, and at about 8 mm. below the aperture on the side of the body-chamber opposite to that which is figured, there is a shallow constriction about 6 mm. wide. There are no remains of the test; the surface of the cast is smooth. The specimen, though evidently much compressed during fossilisation, probably originally had an elliptical cross-



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ORTHOCERAS cf. HERCYNICUM, E. Kayser. (Pl. I. Figs. 6*a*, 6*b*.)

Orthoceras hercynicum, E. Kayser. Abhandl. zur geolog. Specialkarte v. Preussen, etc., Bd. ii. Heft 4 (1878), p. 72, Pl. X. Figs. 7, 8, 11; Pl. XI. Fig. 3 (?).

Among the specimens submitted to me by Mr. Howard Fox there are several examples of the genus *Orthoceras*. The most nearly perfect specimen is represented in Pl. I. Figs. 6*a*, 6*b*. It is a crushed internal cast about 200 mm. in length, of which the body-chamber occupies about 55 mm. The rate of tapering is about 1 in 5, the greatest width at the aperture being about 40 mm., and at the last septum about 28 mm. In its crushed condition the depth of the chambers is about one-third of their width. The siphuncle is slightly excentric (see Fig. 6*b*). Parallel to, and at about 8 mm. below the aperture on the side of the body-chamber opposite to that which is figured, there is a shallow constriction about 6 mm. wide. There are no remains of the test; the surface of the cast is smooth. The specimen, though evidently much compressed during fossilisation, probably originally had an elliptical cross-

section. The septa are rather oblique, but being nearly parallel to the aperture this obliquity may be due in great measure to crushing. On the whole the specimen seems to be comparable with such a form as *Orthoceras hercynicum*, described by Kayser from the limestone at Hasselfelde in the Hartz belonging to the lower part of the Middle Devonian, or with the form which Kayser figures and describes as *Orthoceras* sp. (op. cit., p. 72, Pl. XI. Fig. 1), from the same horizon and locality.

A septated fragment, about 45 mm. long, is possibly referable to this same species.

ORTHOCERAS cf. COMMUTATUM, C. G. Giebel.

(See Text-figures, p. 156, Figs. 1, 1*a*.)

Orthoceras commutatum, C. G. Giebel. Fauna der Vorwelt, Bd. iii. (1852), p. 233.[1]

Another *Orthoceras* indicating a different species is represented in the accompanying figures (Figs. 1, 1*a*). It is flattened, slowly tapering, and about 92 mm. long; the ventro-dorsal and transverse diameters in its present crushed state being 25 and 51, and 23 and 40 mm. respectively. It consists of the internal casts of three chambers, and of part of a fourth, the anterior one being imperfect; the septa are about 21 mm. apart. The siphuncle is not clearly shown, but at the posterior end of the specimen there appears to be a faint indication in a slightly excentric position of something which may have been the siphuncle. There is also a depression at the anterior end, but this seems to be the impression of another organism. The surface of the cast is smooth; there are no traces of any sculpture. This specimen, characterised by its deep chambers and slowly tapering shell, appears to be related to the Devonian form which Kayser has figured (*loc. cit.*, Pl. X. Figs. 1–3; Pl. XI. Figs. 4, 8) as *Orthoceras commutatum*, Giebel, and recorded from the limestone at Hasselfelde in

[1] This is the species which was described as *Orthoceras longicameratum* by Foord (*Cat. Foss.* Ceph. *Brit. Mus.*, pt. i., 1888, p. 80), but this name being preoccupied Foord altered it to *O. nassoviense* (*ibid.*, Corrigenda and Addenda, p. xxxi). The species, however, is evidently the same as that for which Giebel had already proposed the name *O. commutatum*.

the Hartz, a locality which also yields the previously mentioned species, *Orthoceras hercynicum.*

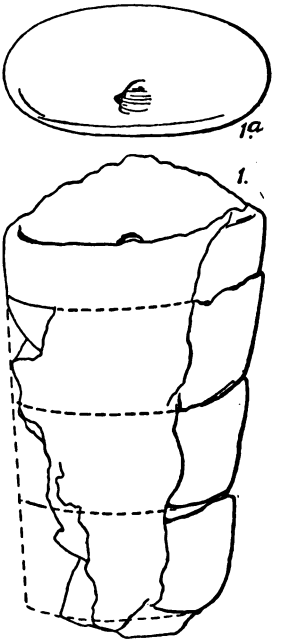


FIG. 1.—*Orthoceras* cf. *commutatum*, C. G. Giebel, showing internal casts of three chambers, and of part of a fourth. 1*a*, anterior end of the same specimen. Cant Hill, St. Minver, Cornwall. Drawn of two-thirds of the natural size. (The reduction of the figure causes the chambers to appear shallower than they really are.)

COPHINOCERAS sp. (Pl. I. Figs. 8*a*, 8*b*.)

The fossil which is here referred to this genus consists of a natural internal cast of a (probably the greater) part of the body-chamber and of the six preceding chambers of a slightly curved shell. It measures on the outer or convex curve about 140 mm., of which the body-chamber occupies about 82 mm. Only one side and a small portion of the other are exposed. The specimen is much flattened, its greatest thickness being only about 28 mm. The greatest width of the fossil is at about the middle of the portion of its septate part, and is about 78 mm., but the boundary of the concave surface of the specimen is not exposed. Of

the chambers that are preserved the oldest is the deepest, being at the middle of the lateral area 12·5 mm. deep; in a similar position the two next are each about 10 mm., the next about 8 mm., the two last being each about 6 mm. deep. Near the anterior end of the specimen there is a very broad, ill-defined, shallow constriction, so that the anterior boundary of the fossil, at least the right-hand side of it, probably represents the border of the aperture. The latter does not appear to have been constricted as in the the genus *Phragmoceras*, but widely open. The fossil appears to bear slight traces of the ornaments of the test. These are most conspicuous on the body-chamber, and consist of several faint parallel longitudinal ridges from 5 to 12 mm. on the outer, convex, or ventral surface; they extend on to the septate part of the shell, where, however, most of them are much less distinct owing to the roughness of the surface of the specimen, but the innermost ridge, which is at about 30 mm. from the outer boundary of the specimen, is very pronounced and somewhat irregular, as though the test here might have been roughly nodose. On the body-chamber these ridges are connected by transverse, fairly closely-set, but slightly irregular lines crossing the interspaces between the ridges in curves which are forwardly-concave. There are also some rather coarser and more irregular wavy lines near the base of the inner or dorsal portion of the body-chamber, but these may not be traces of any surface ornaments. On the inner or dorsal side of the body-chamber a strongly incised line starts from the last septum at about 12 mm. from the inner edge of the fossil; passing forwards and curving over towards the dorsal side, it reaches the boundary of the fossil at a point about 12·5 mm. in advance of the last septum. Judging from observations in other fossils the writer believes this to indicate the boundary of one of the shell-muscles, this being, in fact, the impression of one of the muscle-scars as it was preserved on the inside of the test, the latter having subsequently disappeared. When received the dorsal portion of the specimen was entirely obscured by matrix, and

the fossil looked very much like a portion of a *Phragmoceras*, but the removal of the matrix from the dorsal surface revealed the incised line just referred to, and this suggests to the writer that the fossil is referable to a widely-apertured shell rather than to a form with a contracted aperture such as *Phragmoceras*.

In general appearance the fossil presents some resemblance to the specimen figured by D'Archiac and De Verneuil as *Phragmoceratites subventricosus*[1] from the Middle Devonian of the Eifel, but that species seems to lack the characteristic sculpture of the present specimen.

The fossil appears to be referable to Hyatt's genus *Cophinoceras*,[2] a genus confined to the Middle Devonian, and including both cyrtoceracones or slightly curved forms and gyroceracones or loosely coiled forms. The genotype is *Cyrtoceratites ornatus*, D'Archiac and De Verneuil[3] originally described from the Middle Devonian of the Eifel, but occurring also in the Devonian of Mudstone Bay, South Devon,[4] and to this species the present specimen appears to be allied. Other examples of this genus were figured by Phillips in his work on the Palæozoic fossils of Cornwall, Devon, and West Somerset, and by Whidborne in his Monograph on the Devonian Fauna of the South of England, but the fossil under consideration cannot be definitely referred to any of these, nor indeed to any of the forms described by Holzapfel in his work entitled "Das obere Mitteldevon (Schichten mit *Stringocephalus Burtini* und *Maeneceras terebratum*) im Rheinischen Gebirge."[5]

[1] *Trans. Geol. Soc. London*, ser. 11, vol. vi. pt. 2 (1842), p. 351, Pl. XXX. Figs. 1, 1*a*. Referred to *Cyrtoceras* (*Ooceras*) *flexuosum*, Schlotheim, sp., by A. H. Foord, *Cat. Foss. Ceph. Brit. Mus.*, pt. i. (1888), p. 316.

[2] *Proc. Boston Soc. Nat. Hist.*, vol. xxii. (1883), p. 285. See also E. Holzapfel, *Abhandl. d. k. Preuss. geolog. Landesanst.*, Neue Folge, Heft 16 (1895), pp. 123 *et seq.* Hyatt originally spelt the name *Kophinoceras*, a spelling adopted by Holzapfel; but in Eastman's translation of Zittel's *Textbook of Palæontology* (1900) Hyatt spells the name *Cophinoceras* (p. 522).

[3] *Trans. Geol. Soc.*, ser. 11, vol. vi. pt. 2 (1842), p. 349, Pl. XXVII. Fig. 5.

[4] Described and figured as *Cyrtoceras* (?) *bdellaites* by J. Phillips (*Pal. Foss. Cornwall, Devon, and West Somerset*, 1841, p. 117, Pl. XLVII. Figs. 223*a*, *b*), and referred to D'Archiac and De Verneuil's species by A. H. Foord (*Cat. Foss. Ceph. Brit. Mus.*, pt. ii., 1891, p. 58).

[5] *Abhandl. d. k. Preuss. geolog. Landesanst.*, Neue Folge, Heft 16 (1895).

The specimen appears to have been originally somewhat laterally compressed, but it has doubtless suffered considerable additional compression during fossilisation. We have not ventured to name this fossil, the affinities of which, however, indicate that it is of Middle Devonian age.

PHRAGMOCERAS (?) sp. (Pl. I. Fig. 7.)

The specimen doubtfully referred to this genus is the small natural internal cast figured in Pl. I. Fig. 7. It is the posterior portion of the septate part of a rapidly expanding shell. It is 15 mm. long, its anterior and posterior diameters being 12 and 6·5 mm. respectively, five[1] chambers being obscurely visible. It is slightly curved, and seems therefore to have been the posterior portion of a *Phragmoceras* rather than of a *Gomphoceras* or *Poterioceras*, but it is too imperfect for accurate determination.

AGONIATITES sp. (Text Figures 2, 2*a*.)

The genus *Agoniatites* is represented by a laterally compressed and very much distorted example (see accompanying figures). The specimen consists of the natural internal cast of the greater part of the body-chamber, and of the two preceding chambers, but is so much crushed that its original dimensions cannot be ascertained. It was evidently a rather rapidly expanding shell. The greatest height at the anterior part of the body-chamber is 42 mm. At the base of the body-chamber (see Fig. 2*a*) the height of the whorl from the margin of the umbilicus to the small median lobe of the suture-line is 27 mm., the greatest width of this part of the shell being 16·5 mm. The periphery appears not to have been acute, but a little flattened, there being indications of such a flattening near the base of the body-chamber, the flattened portion being apparently about 2·5 mm. wide. The curve on the inner edge of the body-chamber (see Fig. 2) shows that the fossil was not very widely umbilicated. Although crushed and considerably distorted, the form of the septal surface shows clearly

[1] Six chambers are indicated in the figure.

that the specimen is referable to the genus *Agoniatites*.[1] No signs of sculpture are observable on the side of the body-chamber that is figured, but on the opposite side on the outer portion of the lateral area there are faint regularly-spaced striæ, which are coincident in direction with the septa on the side, but are strongly projected forwards nearer the periphery. This genus is highly characteristic of, if not strictly confined to, the Middle Devonian.

Phillips[2] figured and described from South Devon examples of this genus under the names *Goniatites inconstans* (p. 123, Pl. LI, Fig. 238) and *Goniatites transitorius* (p. 140, Pl. LX. Fig. 227*), whilst Whidborne[3] described and figured in addition to these two other forms *Goniatites obliquus* (p. 56, Pl. V. Figs. 1–3) and *Goniatites fulguralis* (p. 59, Pl. V. Figs. 4, 4*a*), which are also referable to this genus,[4] but

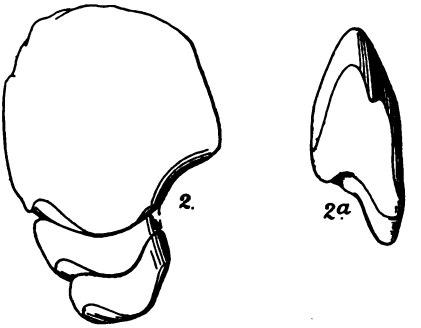


FIG. 2.—*Agoniatites* sp., lateral aspect of internal cast of body-chamber and of two preceding chambers. 2*a*, posterior view of base of body-chamber of the same specimen, showing form of septal surface, the small median lobe being crushed a little to the right side of the specimen. Cant Hill, St. Minver, N. Cornwall. Drawn of two-thirds of the natural size.

the present specimen does not appear to be referable to any of these forms. It seems to be comparable rather with

[1] F. B. Meek, *U.S. Geol. Explor. 40th Parallel*, vol. iv. (1877), pt. 1, p. 99.

[2] J. Phillips, "Figures and Descriptions of the Palæozoic Fossils of Cornwall, Devon, and West Somerset" (*Mem. Geol. Surv.*), 1841.

[3] "Monograph of the Devonian Fauna of the South of England" (*Pal. Soc.*), pt. ii. (1890).

[4] Holzapfel (*Abhandl. d. k. Preuss. geol. Landesanst.*, Neue Folge, Heft 16, 1895, pp. 55 *et seq.*) unites all these forms into one species—with several varieties—for which he retains Phillips's name *inconstans*, a species which he states to be confined to the Upper Middle Devonian.

such forms as Barrande's *Goniatites bohemicus*[1] and *G. tabuloides*,[2] being, however, more inflated than the latter and possibly not so coarsely ornamented as the former. Both of Barrande's forms come from his Étage G, that is, from the Eifelian or lower portion of the Middle Devonian. Whilst, therefore, the present specimen cannot be specifically determined its affinities seem to indicate that it came from rocks of Lower Middle Devonian age.

Notwithstanding the fragmentary character of the specimens described above, their affinities seem to show that they are all certainly of Devonian and most probably of Eifelian or Lower Middle Devonian age.

In addition to the specimens described above, Mr. Howard Fox has submitted to me for examination some very imperfect fossils from other localities in North Cornwall.

Of the two specimens which are marked "E. of Dinham Creek," one seems to be referable to the fairly common species in the Wissenbach Slates that was described as *Orthoceras longicameratum* by Foord[3] (= *Orthoceras commutatum*, C. G. Giebel[4]). The other, nearly 70 mm. long, is a rather rapidly tapering *Orthoceras*, intermediate in this respect between Roemer's *Orthoceras rapæforme*[5] and his *O. subconicum*,[6] but having shallower chambers than either of these species. Both Roemer's species occur in the Wissenback Slates.

Among some specimens labelled "Trewornan" are probably *Orthoceras nassoviense*, Foord (= *O. commutatum*, C. G. Giebel), *O. gracile*, Blumenbach,[7] and a fragment of a *Bactrites*. These species of *Orthoceras* are rather common

[1] J. Barrande, *Syst. Sil. de la Bohême*, vol. ii. pt. 1 (1867), p. 29, Pl. I. Figs. 1–13; Pl. II. Figs. 1, 2; Pl. III. Figs. 15, 16; Pl. CCXLII. Fig. 1; Pl. CCXLIV. Figs. 3, 4.

[2] *Ibid.*, p. 41, Pl. IV. Figs. 1–12.

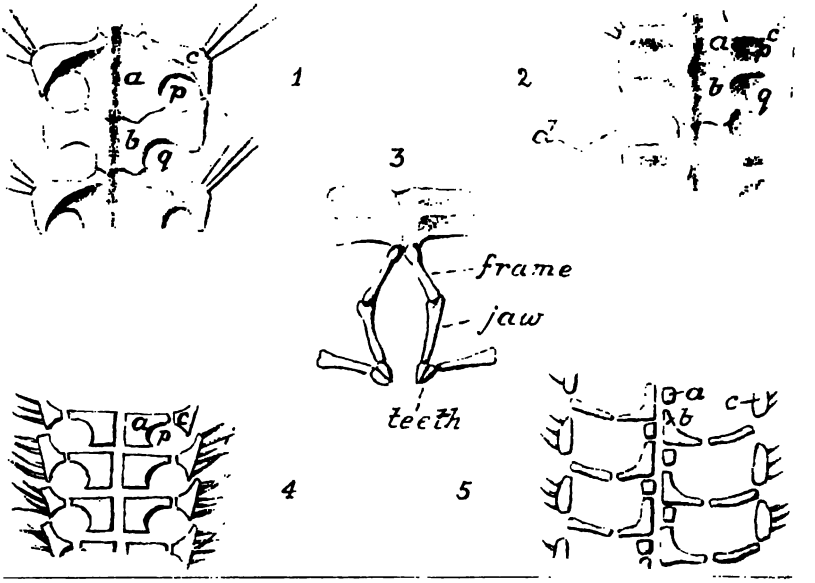
[3] See *antea*, p. 64, footnote.

[4] C. G. Giebel, *Fauna der Vorwelt*, Bd. iii. (1852), p. 233.

[5] F. A. Roemer, *Palæontographica*, Bd. iii. Lief. 1 (1850), p. 16, Pl. III. Fig. 18.

[6] F. A. Roemer, *Ibid.*, p. 17, Pl. III. Fig. 20.

[7] Blumenbach, *Specimen Archæologiæ Telluris*, 1803, p. 21, Pl. II. Fig. 6.



ii

Sympterura Minveri

in the Wissenbach Slates, from which two or three species of *Bactrites* have also been recorded.

There are two rock fragments labelled "Gravel Caverns." Of these one contains an obliquely-septated fragment of possibly a *Bactrites*, or more probably an *Orthoceras*, a little more than 10 mm. long; the other a small water-worn Goniatite 2·5 mm. in diameter, with very indistinct sature-lines, belonging to the genus *Tornoceras*.

EXPLANATION OF PLATE I., FIGS. 6–8.

FIG. 6.—*Orthoceras* cf. *hercynicum*, E. Kayser. *a*, entire specimen reduced to two-thirds of the natural size; *b*, anterior aspect of last septal surface, showing the position of the siphuncle, drawn of the natural size. E. of Cant Cove.

,, 7.—*Phragmoceras* (?) sp. Nat. size. Cant Hill, St. Minver, Cornwall.

,, 8.—*Cophinoceras* sp. *a*, lateral aspect of entire specimen, reduced to two-thirds of the natural size; *b*, a portion of the markings on the body-chamber enlarged. Cant Hill, St. Minver, Cornwall.

(For Figs. 1–5 of this Plate, see Dr. H. Woodward's "Notes on Trilobites from Cornwall," pp. 57–62.)

A NEW OPHIURID FROM CORNWALL.

(*SYMPTERURA MINVERI*, n. g. et sp.)

By F. A. BATHER, M.A., D.SC., British Museum (Natural History).

(Plate II.)

DESCRIPTION OF THE HOLOTYPE.

THE specimen (Fig. 6), kindly entrusted to me for description by Mr. Howard Fox, consists of the oral skeleton surrounded by portions of the disc and of portions of the five rays, all seen from what is believed to be the ventral or actinal surface, and lying on a fragment of the dark slate of the locality, Epphaven. The skeletal parts being preserved in pyrites, it has proved possible to develop the specimen slightly by washing with weak hydrofluoric acid and then brushing with a soft brush. The specimen is, however, so minute and delicate that this process could not be carried very far.

The rays vary in length and, to some extent, in the details shown by each. It is therefore convenient to

number them in a solar direction from i to v, i being the longest and v the next in length. These numbers are not to be taken as implying any certain orientation.

Ray i, from its junction with the mouth-parts to the distal portion preserved, is divisible into nine serially homologous segments, of which the ninth or distal-most is incomplete laterally. There is no evidence as to the complete number of segments that originally composed the ray. Those preserved change slightly in character as they approach and enter the disc, which included one of them certainly and a second possibly; but all show the same elements, except for the lateral spines, which are not borne by the segments within the disc. The lateral spines are borne by the free segments 3–8 in groups of three, each group being at the distal outer angle of each segment. The spines of each group diverge fanwise, but the general outward direction of the middle spine of each triad is slightly distal-wards. It is the clear position of these groups of spines which, more than any other feature, enables one to divide this ray into its nine definite segments. Each segment, however, seems capable of subdivision into a proximal and a distal portion (*b* and *a* in Figs. 1 and 2). There is a median body from which proceed two lateral processes or wings on each side. The distal wing has an approximately straight distal margin, lying about at right angles to the axis of the ray, while its proximal margin is deeply excavate. This excavation is clearer in the more distal segments (Fig. 1, *p*), and its boundary there attains a full semicircle. The proximal wing of each segment forms the proximal boundary of this excavation, and, in the more distal segments, its distal margin is slightly excavate. In the proximal segments (Fig. 2) this wing appears more like a flattened rod, slightly depressed on its proximal margin, while the distal wing is also like a flattened rod somewhat scooped out on its ventral surface. The relations of the wings are perhaps most clearly shown in the eighth segment; here the outer corners of the distal wings seem to overlie processes from the median body (*c* in Fig. 1).

The transverse separation of the median body of one segment from that of the next is not very clear. In the distal part of the ray there are indications of a separation not only between the segments, but between the two halves of each segment. The median bodies are slightly grooved on the ventral surface, so that a continuous open groove runs the whole length of the preserved portion of the ray, and passes into the radial angles of the oral skeleton.

Ray v is in a different state of preservation, having apparently been somewhat twisted over on to the side that lies on the right in the figure, so that the ventral groove, which in its proximal region is median, is seen on the right in the distal region. In the preserved portion of the ray the existence of four distinct segments is pretty clearly indicated by transverse ridges and indentations, also by two spines, one at the distal end of the third segment, the other at the end of the fourth, both on the left-hand in the figure. Apparently there are here preserved only the median bodies, a fact which might suggest that they were distinct elements from the side-wings. There are, however, traces of the wings on the left of the second and third segments. In none of these segments is there a clear indication of a subsidiary transverse division.

The other rays are too incomplete to throw any light on the structure of the segments, but in their proximal segments the side-wings are to be distinguished, especially in ray iv.

The oral skeleton (Fig. 3) is divisible into five radial portions, each of which is bilaterally symmetrical about the radius, and at first sight appears to consist of two curved bars or syngnaths enclosing a lanceolate space, of which the apex is distal, while the proximal ends of the bars approach closely those of the adjacent bars on each side. More minute examination shows that each of the supposed curved bars consists of three elements, to which may be applied the terminology adopted by Dr. J. W. Gregory, the distal element being a "mouth-frame," the proximal one a "tooth," and the intermediate one a "jaw."

Of these three elements the jaws are the longest, and broadened at their distal ends; the distinction between them and the mouth-frames is marked either by a sharp bend or an actual gap. The mouth-frame is about two-thirds the length of the jaw; each pair is joined distally to the median body of the proximal ray-segment. The teeth also are distinguished from the jaw by a sharp bend at the point of union, while they lie a little above the jaw as one views the specimen from the ventral surface. There is no sign of a "jaw-plate" or "torus angularis"; there may have been a small one, or the structures here called "teeth" may represent primitive unfused elements of the torus, such as have been observed in the development of recent Ophiurids. Fewkes states that in *Amphiura* the teeth grow out from the torus and have no independent centres of calcification.

The disc is best preserved in the interradius v–i. It certainly extended up the rays to the distal end of the first segment (*d* in Fig. 2), and perhaps a little further, but whether its outline was straight or concave interradially cannot be decided. It was clothed with minute spines radiating from the centre.

The following are some measurements of the specimen in millimetres:—

Greatest length of the portion preserved	11·5
Diameter of disc	*circâ* 6·5
From centre to distal end of mouth-skeleton	*circâ* 2·0
Width of ray	1·5
Length of lateral spines, at least	1·8
Average length of a segment	·76

Interpretation of the Holotype.

Owing to the difficulties of interpretation, the foregoing description of the rays has been drawn up in as objective a fashion as possible. Some interpretation, however, is a necessary preliminary to any discussion of the relationships of the fossil.

The median body of each segment is undoubtedly the equivalent of the normal Ophiurid vertebra. On the

accepted theory that this vertebra was evolved by the fusion of a pair of ossicles originally alternating, then opposite, and finally joined along the middle or radial line, the present specimen may be described as in a stage of development later than the fusion, but possibly retaining in the median groove a trace of the primitive distinctness of the ossicles. Those ossicles are usually described as ambulacral, and that term may be accepted so far as it denotes homology with the ossicles so named in an Asterid. (See Note at end.)

It was the existence of the median groove that first suggested the determination of the exposed surface of the fossil as ventral. But since such a groove may occur also on the dorsal surface of a vertebra, that evidence is inconclusive. The determination is confirmed, however, by the conspicuousness of the subcircular excavations, or podial pores, in the side-processes, and by the apparent continuation of this groove over the radial angles of the mouth-frames.

As a rule among Ophiurids in this stage of evolution, each vertebra has on each side a single side-process on which abuts an outer ossicle, the so-called adambulacral, and these adambulacrals, which bear the lateral spines, alternate with the ambulacral ossicles or vertebræ. It is a little difficult to interpret the appearances of the present specimen in harmony with such an arrangement. On the assumption that each segment should contain one ambulacral pair (here fused) and one adambulacral pair bearing spines, ray i has been assigned nine segments. But each such segment is seen to have two processes on each side, and the distal one of these bears the spines. For this reason, and because of the appearances in segment 8, it may be supposed that the outer spiniferous portion of the distal process (*c* in Fig. 1) is an adambulacral element. What, then, is the proximal side-process? To this question two possible answers present themselves.

The appearance of a transverse division in the vertebra, between the proximal and distal processes, suggests that

each segment really consists of two ambulacral pairs, of which only the distal one is associated with adambulacrals, the proximal pair of adambulacrals being suppressed. Each of these supposed ambulacral pairs possesses a single pair of lateral processes, but those of the distal pair are partly overlaid by the adambulacral elements. In the distal region of the ray the proximal and distal halves of the vertebra are distinguishable; but nearer the disc and within it they have come closer together, the transverse division has disappeared, and the side-processes are reduced to structures which appear as bars, but are probably flattened laminæ. Thus the vertebræ seen in ray v are, on this explanation, of compound origin.

The preceding interpretation may be compared with Dr. Gregory's interpretation of the structure in the Lower Devonian Ophiurid, *Bundenbachia*[1] (see our Fig. 5). Here "the body of the [ambulacral] ossicle is apparently divided into two pieces by a transverse depression. The adambulacral plates are small and narrow, and support a triangular spine-bearing plate." If, however, as seems legitimate, this last plate be regarded as itself an adambulacral element, then each segment will consist of two ambulacral pairs, and two adambulacral pairs of which one only is spiniferous. The fact that in *Bundenbachia* the ambulacrals still alternate does not affect the composition of the segment. *Bundenbachia* is not to be regarded as a direct ancestor of the contemporary Epphaven fossil, but it suggests the possibility that, during the race-history of the Ophiurids, there may have arisen forms with a tendency to suppression of alternate adambulacrals and to fusion of adjoining ambulacrals.

In *Bundenbachia* there appear to be preserved both adambulacral and ambulacral elements of the subsequently suppressed or coalesced segment. The Silurian *Protaster Sedgwicki* appears to retain the ambulacral elements less reduced than in *Bundenbachia*, while it has lost the adam-

[1] *Proc. Zool. Soc. London*, 1896, p. 1033; 1897.

bulacral elements. In the proximal arm-segments, however, as figured by Dr. Gregory (*op. cit.*, Fig. 1*c*), the existing adambulacrals are forked, a peculiarity suggestive of their compound origin.

Now comparison of the vertebræ of recent Ophiurids with the arm-segments, especially the proximal ones, of our fossil leaves no room for doubt that the depression marked *p* is for the reception of a podium, while that marked *q* is for the insertion of the ventral inter-vertebral muscles. A single arm-segment of a recent Ophiurid, such as *Ophiarachna* or *Amphiura*, is therefore homologous with any one of the whole segments here numbered 1–8. If one of these is really composed of a distal and a proximal half (lettered *a* and *b* respectively in Figs. 1 and 2) the same statement would apply to the recent Ophiurid, and some trace of this origin might be seen in the development. The observations of Professor Ludwig[1] and Mr. J. W. Fewkes[2] on *Amphiura squamata* have shown that the two lateral halves of each vertebra unite first at the proximal and distal ends, leaving a space between. This is suggestive of an origin from proximal and distal elements. On the other hand, each lateral half springs from a single centre of calcification, from which it stretches out in a distal direction, so that the incipient ambulacral element is thicker at its proximal end. This last-mentioned feature is paralleled by the boot-shaped proximal portions of the ambulacral ossicles in the Protasteridæ. At a slightly later stage the ambulacral of *Amphiura* broadens at the distal end, which thus comes to resemble the distal portion of the Protasterid ambulacral. If this distal portion in *Amphiura* were, as indicated by Professor Ludwig's observations, merely an extension of the proximal portion, then it might be inferred that the whole structure, both here and in the various Palæozoic forms alluded to, represented a single ambulacral pair and not two successive pairs. In such

[1] *Zeitschr. wiss. Zool.*, vol. xxxvi. p. 181; 1881.

[2] *Bull. Mus. Comp. Zool. Harvard*, vol xiii. No. 4; 1887.

case one would accept Dr. Gregory's suggested explanation (*op. cit.*, p. 1032) "that the smaller pieces are only triangular, distal portions of the ambulacral ossicles, apparently separated from the proximal portion[s] by a groove." Dr. Gregory further suggests that these grooves or depressions "were for the lodgment of the ventral muscles which moved the arms." A far more probable explanation surely is that they were for the reception of the branches from the radial water-vessel to the podia. This explanation, however, consonant as it is with the facts of devolopment in *Amphiura*, reminds one of another difficulty. Professor Ludwig (*op. cit.*, p. 185) has pointed out that, whereas the so-called ambulacrals of Asterids lie at right angles to the perradius and between the successive branches and podia, those of Ophiurids lie parallel to the perradius and across the branches to the podia. Now if, as we have every reason to believe, the Ophiurids were derived from Asterids, it is hard to see why this change should have taken place. That is the difficulty, but it is a difficulty that disappears if we suppose that the vertebra is really compounded of two successive ambulacral pairs in the manner outlined above. The remaining objection to this latter hypothesis is that, as Dr. Gregory has pointed out, it postulates the suppression of alternate podia. Nevertheless, similar fusion and concomitant suppression are not so unknown among Echinoderms as to render this objection a fatal one.

The suggestion that the vertebræ of Ophiurids are composed of two successive ambulacral pairs certainly cannot be proved with the evidence at our disposal. But it is doubtful whether it can be disproved, and I therefore make it to promote a search for further evidence *pro* or *con*.

Two other features in the present specimen need discussion, and may perhaps throw light on the problem just posed. The first of these is the fact that the broadest and stoutest portion of each arm-segment appears to be the distal half (marked *a* in Fig. 1), whereas in the developing *Amphiura* and in the adult Protasteridæ the reverse is the

case. This character is also found in *Furcaster palæozoicus* as figured by Mr. Stürtz, in *Ptilonaster princeps* of J. Hall, and in *Lapworthura Miltoni* as interpreted by Dr. Gregory (see our Fig. 4). In the Epphaven fossil the feature is to some extent accounted for by the supposed fusion of a spiniferous adambulacral element with the distal wing of the ambulacral; but in *Lapworthura* and *Furcaster* this wing, while unconnected with the adambulacral, is still more preponderant. In some other early Palæozoic genera, e.g. *Eugaster*, J. Hall, and *Eophiura*, Jaekel, the wing is neither distal or proximal, but arises half-way up the ambulacral, so that one cannot say to which of two successive segments the podium belongs: in fact, the structure is in this respect absolutely that of an Asterid.[1] These differences call for some explanation. Starting from the indifferent Ordovician type of *Eophiura*, we may suppose that in one series of genera (*e.g.* Protasteridæ) the wing moved towards the mouth, while in another series (*e.g.* Lapworthuridæ) it moved away from the mouth. In both series the podium ultimately became enclosed within the substance of (apparently) a single ossicle; but, if this took place by a subsequent lateral outgrowth of stereom, then in the former case the vertebra must have enclosed a podium distal to itself, and in the latter case a podium proximal to itself. Thus the relations of the vertebræ to the podia would be fundamentally different in the two lines of descent. On the other hand, alternate podia may, as suggested on a previous page, have been enclosed by the union of successive pairs of vertebræ, and this type of structure may be the one seen in process of development in the arm-segments of our fossil, and the one that persisted to the present day.

The second feature worthy of attention is the considerable space that seems to intervene between the distal wing of one segment and the proximal wing of the next. This is

[1] See Dr. O. Jaekel's interesting account of genera from the Lower Palæozoic rocks of Bohemia, intermediate between Asterids and Ophiurids, *Zeitschr. Deutsch. geol. Ges.*, lv. Protok. pp. 106–13; 1904. References to the older literature will be found in Dr. Gregory's oft-quoted paper.

conspicuous in the distal region of ray i, where, further, the depression (*q* in Fig. 1) markedly resembles the podial depression (*p* in Fig. 1), and differs from it mainly in being rather nearer the axis of the arm. The theory that the Ophiurids are descended from Asterids does not explain the evolution of such an interspace, and the general tendency to shortening and approximation of the vertebræ, shown in the history of the Ophiurids, leads one to enquire why there should ever have been introduced a stage in which, as in the Devonian *Ophiurina*, the recent deep-sea *Ophiohelus*, and the young *Amphiura*, the vertebræ have so far departed from the primitive type as to become axially elongate. This stage has been regarded as primitive by Lyman, Ludwig, and other zoologists, but in theory and fact it is "primitive" only so far as the later forms are concerned, while with reference to the complete series it is "intercalated."

Recurring to the hypothesis that the vertebræ are compounded of successive pairs of ambulacrals, we find in it an explanation not merely of this curious elongation of the arm-segments in general, but of the interspaces between them in this genus (lettered *q*). An objection to the hypothesis was the necessity for assuming the suppression of alternate podia. Here, it may be, is evidence of a stage in which those podia were not yet suppressed, though perhaps somewhat atrophied. If both depressions (*p* and *q*) were for the reception of podia, then their alternate approximation to and removal from the perradius may be compared with the similar phenomenon in Asterids.

Whether the features just discussed be or be not accepted as evidence in favour of the compound origin of the Ophiurid vertebra, they demand some explanation; and it may be added that the same hypothesis will perhaps furnish an equally needed explanation for the hitherto unexplained differences that obtain between Palæozoic genera of Ophiurids in the relations of the adambulacrals to the ambulacrals.

The origin of the Ophiurid mouth-skeleton also may be

illuminated by the preceding hypothesis, which is in full harmony with the opinion that many more arm-segments enter into the composition of that structure than is the case in Asterids, an opinion based on embryological research by Dr. O. zur Strassen,[1] and on palæontological investigation by Dr. O. Jaekel in the paper quoted above. In this region of the ray, at any rate, adambulacrals and podia must have been suppressed in all Ophiurids. We may here note the apparent absence from our specimen of the adambulacral elements known as side mouth-shields, as well as of the peristomial plates. The latter are wanting in most early Ophiurids, a fact confirmatory of Dr. zur Strassen's conclusion that they are not ambulacral elements, but "secondary calcifications confined to the interradial region."

SYSTEMATIC POSITION.

In considering the systematic position of this fossil we have two systems to choose from: one, that proposed by Dr. Gregory in the paper above quoted, and adopted by him in *A Treatise on Zoology* (ed. Lankester, London, 1900); the other, the latest classification by Mr. B. Stürtz (*Verh. nat. Ver preuss. Rheinlande*, lvi. p. 198, 1900). The two classifications have much in common, and, without discussing their respective merits, it will be convenient to start with Dr. Gregory's as more accessible to English readers.

The union of the ambulacrals into vertebræ removes the fossil from the Order Lysophiuræ and from the Streptophiuran Family Ophiurinidæ, while the absence of a covering integument or scutes prevents it being placed in any of the other Orders or in any Family of Streptophiuræ other than Lapworthuridæ or Eoluididæ. Of these two Families the former has no ventral arm-plates, and the latter, while having ventral ones, has no dorsal arm-plates, except in *Aganaster*. If the exposed surface of this fossil

[1] *Zool. Anzeiger*, xxiv. p. 609; Nov., 1901.

be rightly regarded as ventral, the specimen must belong to the former Family. The genera herein contained are *Lapworthura*, Greg., *Furcaster*, Stürtz, and *Palastropecten*, Stürtz (syn. *Palæospondylus*, Stürtz). The last of these differs from the Epphaven fossil in almost every respect, but the two others present a slight general resemblance in arm-structure. In each, for instance, the vertebral body has distal wings, and in *Lapworthura* these wings surround large subcircular pores; but in both the adambulacrals have a different position, while there is no proximal wing, although the diagram of *Lapworthura* given by Dr. Gregory and here repeated (Pl. II. Fig. 4) shows a minute incipient process. In the known species of these genera also the disc extends further down the rays, which are relatively wider, while the proportions of the various elements of the mouth-skeleton are different.

The Family Eoluididæ includes *Eoluidia*, Stürtz (syn. *Eophiurites*, Stürtz), *Eospondylus*, Greg., *Miospondylus*, Greg., *Aganaster*, Miller and Gurley (syn. *Ophiopege*, G. Böhm), and perhaps *Cholaster*, Worthen and Miller. The last two have both ventral and dorsal arm-scutes, while as for the others they differ in much the same respects as do *Furcaster* and *Lapworthura*, only to a greater extent and with no superficial resemblance.

It seems therefore safest to place this fossil in the Lapworthuridæ, with the diagnosis of which it agrees so far as the structure is known. If the subdivision of Gregory's Family into Lapworthuridæ, Furcasteridæ, and Palæospondylidæ (i.e. Palastropectinidæ), as proposed by Stürtz, should be accepted, our fossil would still be most appropriately placed in Lapworthuridæ. It is, however, quite impossible to refer it to *Lapworthura* itself, and a new genus must be established for its reception. From a geological point of view it would have been more interesting could one have referred it to some known species, or at least genus, found in the Devonian of Germany. But repeated comparison with the rich material in the British

Museum has proved this course inadmissible, whatever errors there may be in the details of the present interpretation.

SYMPTERURA,[1] nov. gen.

A Lapworthurid with spinulose disc extending to second arm-segment, with oral skeleton of teeth, long jaws, and short mouth-frames (torus not seen), with free arm-segments containing a vertebral ossicle, possibly compound, grooved ventrally and provided on each side with two wings, to the distal of which is attached an adambulacral spiniferous element.

Genotype. *Sympterura Minveri*, n. sp.

This being the only known species, a diagnosis is impossible, but attention may be directed to the relative narrowness of the rays, the extension of the disc, and the length and number of the spines.

Holotype, a unique specimen detected by Miss Barbara Legg in the blue slate of Epphaven, which is a cove between Lundy Beach and Trevan Point in Portquin Bay, in the Parish of St. Minver, near Padstow, North Cornwall. When Mr. Howard Fox was so good to send me the specimen for examination, I acknowledged its receipt in a rather informal letter, extracts from which have since been published by him (*Trans. Roy. Geol. Soc. Corn.*, xii. p. 752, Sept., 1904). One sentence ran: "So far as I can judge without more prolonged study [the fossil] is either *Ophiurina* or a close ally." The structure had not then been developed by etching and brushing. It is now quite clear that the specimen has nothing to do with *Ophiurina*, which is in the Lysophiuran stage, with long rod-like unfused ambulacrals. Mr. Fox has since kindly presented the specimen to the British Museum, where it is registered E 5,036.

Horizon.—The rock is certainly Devonian, but on its precise age the present specimen, being of a new generic

[1] σύν and πτερόν, "paired wings," and οὐρά, "tail," as in *Ophiura*, *Lapworthura*, etc.

type, can throw little light. The stage of evolution at which *Sympterura* stands, namely, primitive Streptophiuran, is fully consistent with a Lower Devonian age.

NOTE.—In this paper I have used the term "ambulacrals" for the elements of which the Ophiurid vertebra is composed, and in so doing have followed the general custom. But many writers, from Johannes Müller onwards, have contended that the so-called ambulacrals of Asterids and Ophiurids are not homologous with those plates in Echinoidea for which the term was originally proposed. This contention has much in its favour. At any rate, the so-called ambulacrals of Asterids are homologous with the flooring plates of the subvective groove in Edrioasteroidea, and not with the covering plates, which latter are usually called ambulacrals, as in Pelmatozoa generally.

For practical purposes also, I have used the ordinal names Streptophiuræ and Lysophiuræ, proposed by Mr. F. J. Bell and Dr. J. W. Gregory respectively. But it seems to me that the divisions adopted by my friends and colleagues represent stages of development rather than divergent groupings, and while admitting the great interest and value of the conceptions, I cannot follow Dr. Gregory in ranking them as Orders.

EXPLANATION OF PLATE II.

FIG. 1.—*Sympterura*, semi-diagrammatic reconstruction of the 8th arm-segment and part of the 7th. *a*, distal portion of the vertebra; *b*, proximal portion; *c*, adambulacral; *p*, podial depression or pore; *q*, interspace, occupied, at least in part, by intervertebral muscles. × 18 diam.

,, 2.—*Sympterura*, semi-diagrammatic reconstruction of the 2nd arm-segment and part of the 1st. *a*, *b*, *c*, *p*, *q*, as in Fig. 1; *d*, border of disc. × 18 diam.

,, 3.—*Sympterura*, semi-diagrammatic reconstruction of part of the mouth-skeleton. × 10 diam.

,, 4.—*Lapworthura*, diagram of the arm-structure, after Gregory, *Proc. Zool. Soc.* London, 1896, p. 1037. *a*, *c*, *p*, as in Figs. 1 and 2.

FIG. 5.—*Bundenbachia*, diagram of the arm-structure, after Gregory, *op. cit.*, p. 1034. *a*, *c*, *b*, as in Figs. 1 and 2. Dr. Gregory is not responsible for the lettering in Figs. 4 and 5.

,, 6.—*Sympterura Minveri*, the unique specimen. The numbering of the rays is for convenience only. In drawing this figure I was helped by preliminary sketches made by Mr. W. Lewis before the specimen was fully cleaned. × 7 diam.

All figures represent views of the ventral surface. The drawings are reproduced by the London Stereoscopic Company, Limited.

As Mr. W. A. E. Ussher of the Geological Survey was good enough to show me some of his typical Upper Devonian rocks on both sides of the Tamar, and has since visited with me the Padstow and St. Minver districts, I have asked him to add to this paper his own conclusions as to the age of these rocks.

NOTES BY W. A. E. USSHER.

THE rocks in which the limestone bands on either side of the Camel occur, as shown in De la Beche's maps, were placed by me in the Middle Devonian in a forecast on the probable relations of the Devonian rocks of Cornwall contributed to the *Trans. Roy. Geol. Soc. Corn.* in 1891. This error was due to the fauna said to occur in these limestones by Holl and De la Beche, quoting Phillips—a fauna which consisted of an admixture of Middle and Lower Devonian forms. The researches of Mr. Fox, the results of which were published in 1894, have conclusively proved that the rocks in question belong to the Frasnien or lower part of the Upper Devonian, and that the fauna is that of the Büdesheim type, so well known to every student of Devonian stratigraphy. The Büdesheim fauna was discovered in Saltern Cove, near Paignton, in purple slates many years ago by the late J. E. Lee, afterward by

me at Ivy Cove (south of Saltern Cove), at Wrigwell (west of Newton Abbot), in 1888, at Warren Point the Devon side of the Tamar, and between Earth and Ince Castle by the Lynher Estuary in East Cornwall in 1893.

I have lately had the satisfaction of being personally conducted by my friend Mr. Fox over all the localities in which he discovered this assemblage of small *Goniatites*, *Bactrites*, and *Orthoceratites*. The points that struck me most were the close correspondence between the rocks of Padstow, Trevone, and St. Minver, and their representatives in the Plymouth area. In both districts we have a series of dark slates locally containing limestones, in the form of beds, nodules, or lenticles. The north coast sections of Cornwall offer much greater facilities for the study of these associations than is afforded by the creek sections of the Tamar estuary; a comparison, however, of the Trevone Bay coast with the Landulph coast, near Nail Point by the Tamar, will leave little doubt of their correspondence.

In both areas the prevalent organisms are *Styliolæ*, which are very plentiful, especially on the north coast. I believe they were first discovered in England in the dark slates of Lower Compton, near Plymouth, by me in 1892, identified by Professor Rupert Jones, F.R.S. In both areas the dark slates pass upward into green and purple slates. The variegated purple and green slates of St. Kew and St. Minver, wrongly correlated by De la Beche with the variegated (Lower Devonian) slates of Watergate Bay, are well represented between Liskeard and Plymouth, and contain *Entomis* and *Styliola*, also small *Tentaculites*. *Entomis* has not yet been certainly identified on the north coast, but *Styliola* and small *Tentaculites* were obtained by us in the cliff of Butter Cove, near Stepper Point, in the purple and green slates.

The Middle Devonian slates of both areas are not sufficiently differentiated lithologically from the Upper to furnish a recognisable boundary. Beyond *Zaphrentis*, *Pleurodictyum*, an occasional trace of trilobites im-

perfect coralline fragments, and, on the north coast, *Pteroconus* (*Nereitopsis*, Green), found by Mr. Fox in the lower (Eifelian) part of the division, they exhibit few recognisable organisms in the areas west of the Plymouth limestone.

The chief difference is the paucity of volcanic rocks in the Upper Devonian in the north coast district, as contrasted with their development in the Upper Devonian area between Plymouth and Liskeard. The development of intercalated limestones and slates in what is known as the Marble Cliffs seems to be unprecedented, but, perhaps, if the limestone intercalations at Rock and Trevone, and such a section as that of the Landulph coast, were seen in a high cliff in vertical succession their thickness would be much greater than one is apt to infer from the south coast cliff sections.

All the specimens referred to in these papers will be deposited in your Geological Museum, Penzance, with the exception of the new Ophiurid *Sympterura Minveri* and the Cephalopod *Cophinoceras*, which I have presented to the British Museum.

1189
G.S.P.

Vol. XIII. Part II.

TRANSACTIONS

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OF

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INSTITUTED FEBRUARY 11th, 1819.

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ANNIVERSARY ADDRESS OF THE PRESIDENT,

DR. RICHARD PEARCE, F.G.S.

To the General Meeting, 31 *October*, 1905.

LADIES AND GENTLEMEN,—In tendering you my thanks for the distinguished honour you have conferred on me in electing me President of your Society, I may perhaps be permitted to say that for a period of over forty years I can hardly claim to be identified with the scientific institutions of Cornwall. It is true that in my early training in the county, at a period when its principal industry—mining—was in a prosperous condition, and a desire was beginning to be felt for scientific information, I played some small part in connexion with the Mining School at Truro and the Miners Association of Cornwall and Devon.

The greatest part of my life, however, has been devoted to industrial science, and I have been chiefly engaged in trying to solve certain problems connected with the metallurgy of gold, silver, and copper.

I have thought it desirable to refer briefly to the fact that my qualifications as President of this Society may be regarded with some degree of doubt, and hence my wish to place myself on a proper footing with those members of the Society whom I have not the pleasure of knowing.

In looking around me for the purpose of selecting a subject on which to address you on this occasion, I am met with rather a

serious difficulty, as my long residence abroad has in a great measure prevented my keeping in close touch with the subjects which have always been considered of special interest to members of this Society, and I have come to the conclusion that a few remarks bearing more especially on the Mining Industry of Cornwall, and those questions which refer more particularly to economic geology which come under the limited scope of my own experience, may, perhaps, at this time be acceptable.

During my recent visits to Cornwall, after a rather prolonged absence, I have been impressed with the great change that has come over its principal industry—mining—during a period of some twenty-five years. Forty years ago, a stranger coming into Cornwall would have been struck with the abundant evidence of industrial success. The Caradon group of mines; Fowey Consols; Par Consols; Charlestown United; the mines in the districts of St. Day, Redruth, Camborne, Wendron, Breage, St. Ives, and St. Just were successfully worked and added greatly to the general prosperity of the county.

At the present time we are met with evidences of decay and abandonment of an industry which had, for more than a century, played such an important part in the community's welfare.

The reputation which Cornwall enjoyed for a number of years, as a mining Mecca, has in a great measure disappeared, and little remains to be seen at the present time except here and there dismal-looking monuments of departed greatness.

The classic veins of Cornwall have formed the subject for scientific discussion by geologists and scientific men generally in almost every part of the mining world.

Within the short period of half a century, and prior to the discovery of copper in Chili, Australia, and the Cape, Cornwall may be said to have been the principal producer of that metal, and with the exception of a certain supply from Banca in the East Indies, Cornwall contributed the world's supply of tin.

The present yield of copper in Cornwall is practically nil, and the Straits Settlements have so far eclipsed our county

(Cornwall) as a source of tin, that the latter presents quite an insignificant figure in the total world's supply, its present annual production being considerably less than that of the Republic of Bolivia.

The question which naturally presents itself to the minds of those who are interested in the welfare of Cornwall and the success of its industries is: Are we justified in coming to the conclusion that the time is at hand when Cornwall is no longer capable of producing copper and tin, and that its mines are exhausted?

I think that I am correct in stating that little or nothing has been done, during the last half-century, with a view of determining whether mineral of value is to be found outside of the ordinary beaten track, if I may be allowed the expression.

My predecessor in office, Mr. J. H. Collins (with his usual keen insight), has on more than one occasion drawn attention to this matter, but, so far as I can remember, intelligent systematic prospecting has been entirely neglected in Cornwall.

It is scarcely conceivable that districts which have been abundantly proved to contain ores of great value have become exhausted. A point may have been reached in their history where mining ceased to be remunerative, under the conditions which prevailed at the period of their abandonment. Certain factors, such as high cost of mining, low price of metals, would in all probability play a very important part in reference to the economic working of a mine; but taking the altered condition of things as they present themselves to-day, viz. improved facilities for mining, modern methods for ore dressing, or concentration, a higher price for metals (owing to a more extended demand), not to mention a possibly more liberal arrangement with the lords of the soil, mines that could only be operated at a loss fifteen or twenty years ago might now be worked profitably.

If, as I fear, I have already gone beyond what I might be expected to say as President of a, strictly speaking, scientific society, in referring at some length to the commercial side of this ques-

tion, my love for my county, and my intense regret at finding such apparent apathy and indifference in regard to the welfare of Cornish mining, as appears to exist at this time, must be my excuse.

It will perhaps be of some interest to consider briefly the advantages to be derived from a careful study of the geological conditions which accompany mineral deposits, and by way of illustrating the importance of such work in connexion with mining operations, I refer you to Bulletin 227, published by the United States Geological Survey (Charles D. Walcott, Director), and with your permission I will quote briefly from this interesting publication.

> "The economic work of the Survey has, from the first, been made very prominent. In mapping the geological formations, the relations of the rock to the ore bodies is necessarily studied in considerable detail. The distribution, mode of occurrence, and genesis of the ores are also investigated in order that their economic importance may be properly estimated, and their development carried on with the greatest economy. Two sorts of data result from these studies: first, those which throw light on the general laws governing the formation of ores, and other minerals of economic importance; and second, facts of geologic structure and occurrence, which are immediately useful in the development of the particular ore bodies studied.
>
> "The Survey has consistently occupied the position that its greatest and most peculiar usefulness lay along the first mentioned line of research. The principles controlling mineral deposition, and the laws governing the occurrence of ore bodies, can be satisfactorily determined only as a result of the comprehensive study of many mines and mining camps. This work is beyond the reach of individuals, but is appropriate to the national organization.
>
> "That the Survey work does actually result in the development of those principles, is evidenced by the simultaneous formulation by Emmons, Van Hise, and Weed of the doctrine of secondary enrichment of metallic sulphides, by Emmons' statement of lateral segregation, as applied to the genesis of the

Leadville ores, and by Van Hise's development of the principles of metamorphism in relation to ore bodies, and by many similar results."

Evidence of this kind, coming from such a reliable source, will convey, more than any words of mine, the importance of recognizing the value of scientific investigation in connexion with mining operations.

My long residence in Colorado, which is one of the great centres of mining in the United States, has enabled me to bear testimony to the value and importance of the work of the United States Geological Survey, for, during the last thirty-four years, I have had opportunities of seeing the discovery and development of the principal mineral deposits of the Rocky Mountains, and have been able to appreciate fully the important services rendered by such men as Emmons, Hague, Becker, and others connected with the Survey.

In this connexion we are led to inquire what has been done by the Geological Survey of the United Kingdom for the benefit of Cornish mining? If I have been correctly informed, little or nothing has been accomplished since the time of Sir H. Delabeche, nearly seventy years ago, until very recently, and the valuable contributions to this Society by J. B. Hill and D. MacAllister would indicate that the Survey authorities have at last been impressed with the importance of a careful and exhaustive study of the economic geology of Cornwall.

During the last few years considerable attention has been directed to the subject of ore deposits, with a view of determining their origin and the relation they bear to the rocks in which they occur. The mining industry has taken such marvellous strides, the world over, in the last two decades, that opportunities for scientific investigation have increased, and in many localities the developments in the more important mining centres are being watched by carefully trained scientific observers, who are waiting with the keenest interest any developments which will throw light on the subject of the genesis of ore deposits.

Prof. S. F. Emmons, in his presidential address, read before

the Geological Society of America a year ago, entitled "Theories of Ore Deposition Historically Considered," traces, in a very interesting and comprehensive manner, the gradual development of this branch of science from a very remote period down to the present time.

He briefly outlines the researches and theories of scientific men who have made "ore deposits" a subject of special study. The works of Elie de Beaumont, Bischof, Daubrée, Von Cotta, Sandberger, Stelzner, and others belonging to what he calls the scientific period, as distinguished from the verification period, which covers the last quarter of the past century, and he aptly states :—

> "That the investigations now to be carried on with more perfect methods, or in the light of recent advances in the science, would seem more properly verifications of old theories than the propounding of new ones."

Prof. Posepny's exhaustive monograph on "The Genesis of Ore Deposits," read at a meeting of the American Institute of Mining Engineers in 1893, attracted the attention of geologists and mining engineers, and the theories which were advanced by him, as a result of a very careful study of vein phenomena and of ore deposits generally, seemed to have found favour in the opinions of mining authorities, with some few exceptions. It had the effect of stimulating discussion on the part of those who favoured his deductions, as well as others who were not, strictly speaking, strong adherents to his theories and conclusions; and I would take the opportunity of referring you to an interesting volume which has recently been published, entitled *Genesis of Ore Deposits*, in which may be found papers and discussions presented at meetings of the American Institute of Mining Engineers, by Posepny, Le Conte, Vogt, Van Hise, Emmons, Kemp, Lindgren, Rickard, Weed, and others. This volume contains an immense amount of highly interesting reading, in reference to modern theories and researches on the subject of ore deposition.

According to Posepny's views, ore deposits are formed by the

deep-seated circulation of water by descending and ascending currents, high temperature and increased pressure favouring the solubility of the metals and their ores at great depths, which are again precipitated on their approach to the surface.

It is a fitting opportunity, I think, for me to draw attention to a statement I have recently found in a little book published in 1855, and entitled *Cornwall and its Mines and Miners*, by the author of *Our Coal and Our Coal-pits*. At page 122, referring to the "original formation of veins," the author says:—

> "Mr. Fox assumes as sufficiently proved, the origin of fissures from various causes, and at various intervals, and their enlargement from time to time; the progressive filling up of such fissures; and their penetration to great depths and regions of high temperature. He shows the probability of the circulation of heated water in them by ascent and descent, and the deposition of quartz and other earthy substances in cool parts."

The reader is also referred to Reports of the British Association for Science for the year 1838.

From this it would appear that the views held by Daubrée in 1841, and by other observers since that time, had been anticipated by the late Mr. Robert Ware Fox, F.R.S., and the main principles involved in the recent theory advanced by Posepny and others correspond almost exactly with Mr. Fox's views on vein formation.

Although Mr. Fox's conclusions on the formation of mineral veins are largely based on his electrical theory, we have the strongest evidence that he had the clearest conception as regards the deep-seated source of the metals which were brought to the surface through the agency of circulating water under high temperature and pressure.

Dr. Waldemar Lindgren, of the United States Geological Survey, presented a most important paper at the Washington meeting of the American Institute of Mining Engineers, February 1900, which will be found in the volume already referred to, *Genesis of Ore Deposits*. The title of the paper is "Metasomatic Processes in Fissure Veins." The subject is treated from a chemical microscopic point of view. He defines metasomatism

(the name indicating "change of body") as a variety of metamorphism which involves a change in the chemical composition of rocks by the addition or subtraction of a substance.

Dr. Lindgren quotes a large number of examples, which indicate the correctness of his conclusions, from almost all the mining districts known, and he refers especially to Cornwall as being the birthplace, as it were, of the theory first suggested by Daubrée, and later by Cotta.

These scientists were led to their early investigations from the occurrence of pseudomorphs of cassiterite after feldspar, which I believe were first discovered in the old Wheal Coates Mine at St. Agnes, and described in the Journal of this Society by Mr. Davey in the year 1832.

Ore deposition, by this metasomatic process, as described by Lindgren, is abundantly illustrated in connexion with the tin deposits of Cornwall. The occurrence of pseudomorphs of oxide of tin after feldspar, at Wheal Coates, and later on at Balleswidden Mine, St. Just, and Phœnix Mine, Liskeard, was proof positive that a very important change had taken place by chemical agency, and that the original feldspar has been substituted in whole, or in part, by oxide of tin.

We have only to examine the granite in which most of the tin deposits are found in Cornwall to discover evidences of intense chemical action. The feldspar, which seems to be less capable of resisting this action, has been partly, and in some cases wholly, removed and given place to chlorite, and here we have an example of the decay and destruction of one mineral and the building up of another, by the readjustment of the elements constituting the feldspar, with some trifling additions from outside sources.

In some localities in Cornwall, and particularly in the St. Ives district, the feldspar of the granite has been replaced by tourmaline (schorl), and in this case we have to account for the presence of certain elements entirely foreign to the feldspar, viz. boron and fluorine, which are claimed by some geologists to have

played an important part in the impregnation of the rock and veins by oxide of tin. Although Cornwall, and perhaps one or two other tin-producing districts in the world, furnish abundant evidence of the existence of boron and fluorine, there are other important tin-bearing localities which furnish little or no evidence of the existence of those two elements. I would refer to the districts of the Malay Peninsula and the tin mines of Bolivia, which, at this time, furnish by far the largest bulk of the tin produced in the world.

In the specimens of lode tin from the Straits which I have had an op[illegible] examining, I have not been able to discover any indication of boron or fluorine in the form of tourmaline or fluorite, but I have noticed well-marked evidences of chlorite.

I have had excellent opportunities of studying characteristic examples of tin ores from Bolivia, and until very recently I have not been able to recognize any evidence of tourmaline. I noticed a few months ago, in some specimens submitted to me from the Tres Cruces district, Bolivia, a hard, compact, black mineral, together with some very fine delicate needles of a greenish colour, and associated with tin, which I suspected might prove to be tourmaline, and was able to demonstrate the correctness of my opinion, through the kindness of Prof. Kemp, of Columbia University, New York, by a microscopic examination.

I have since learned from Mr. L. J. Spencer, of the Natural History Museum, that he has also observed the existence of minute crystals of tourmaline in some Bolivian tin specimens which he has examined. Mr. Spencer also informed me that in one instance only could he trace any evidence of fluorite.

Still more recently, Mr. MacAllister, of the Geological Survey, has proved the presence of tourmaline and chlorite, by a microscopic examination of a specimen of tin ore from Bolivia; so we have the evidence from three separate sources of the existence of tourmaline in Bolivian tin ores, but nowhere is the quantity sufficient to warrant our claiming anything more than an insignificant part in the original deposition of the cassiterite.

To return to the subject of metasomatism, to which I have already referred at some length, I think that we may fairly assume that districts which indicate that this form of metamorphism had taken place on a considerable scale, would naturally commend themselves to prospectors who are interested in the discovery of ore deposits, and I do not hesitate to claim that Cornwall offers exceptional advantages in this direction, for, from the banks of the Tamar to Cape Cornwall, wherever eruptive rocks such as granite or elvan are found, abundant evidences exist of intense mineralizing influences.

We have an example before us of the change of quartzite to cassiterite, which came under my notice some few months ago in some specimens of tin ore from Bolivia, in the form of rounded water-worn pebbles (stream tin). The pale yellow colour of the specimens led me to believe that the mineral, or tin rock, was originally quartz porphyry, and I submitted the samples to Dr. Lindgren, of the United States Geological Survey, who had two or three sections prepared for microscopic study. He unhesitatingly came to the conclusion that they were quartzite in differing degrees of impregnation by cassiterite. This change can only be explained by supposing that quartz grains had been removed by some agent or solvent, which probably at the same time deposited the cassiterite in the place of the quartz.

We have, too, an interesting example of a pseudomorph of tin after feldspar in quartz porphyry from Bolivia.

If I have not already exhausted your patience, I would like to direct your attention to another subject which is of great interest to economic geology, and I refer to what has been termed secondary enrichment in veins. It is well known that certain ore deposits have been materially changed from their original character from the surface down to a point which may be regarded as the water-level, as a result of oxidation due to the circulation of surface waters containing oxygen through the upper portions of the lodes.

The subject has received little attention, however, beyond a

general recognition of the fact, until within the last few years. It has been demonstrated by Mr. S. F. Emmons and Mr. W. H. Weed, after a careful study of the extensive copper deposits in the Butte district, Montana, that the upper portions of the veins, which have been worked so extensively in that localty, have undergone a material change from their original condition. The copper and iron pyrites, which must have formed a part of the vein filling at some remote period, have undergone oxidation by the circulation of surface waters. The sulphate of copper resulting from this slow process of oxidation was carried down in solution in water to a depth below the zone of oxidation, and the copper was precipitated, in contact with deposits of the mother mineral (copper pyrites), in the form of copper glance and bornite of great richness and value. This same change has been observed by Lindgren at the Clifton Morenci Mines of Arizona.

Conditions very similar to those I have referred to were experienced in many of our Cornish mines in their early history, when copper played such an important part in mining.

In one of the mineral cases at the Museum of the Royal Institution of Cornwall may be seen a collection of copper ores and gossans collected in the year 1840 by John Bain, of Portreath. I have recently had an opportunity of studying this interesting collection, and I have observed much the same conditions as are said to exist in other localities.

A specimen from Levant Mine shows a mass of rich copper glance, found at a depth of 200 fathoms.

"Tincroft"—copper glance at a depth of 90 fathoms.

"Providence" (an interesting series):—

12	fathoms	from	surface—	gossan.
20	,,	,,	,,	black oxidized ore.
35	,,	,,	,,	copper and iron pyrites.
56	,,	,,	,,	gossan.
68	,,	,,	,,	massive copper pyrites.
72	,,	,,	,,	massive rich copper glance.

"Carn Brea":—

50	fathom	level—	solid copper pyrites.
70	,,	,,	gossan.
70	,,	,,	massive copper glance.

It would seem that oxidation must have taken place along certain horizontal lines to account for the existence of alternate zones of copper pyrites and gossan, as in the case of the examples from Wheal Providence.

It is, I believe, generally recognized that copper in its original, primitive condition, existed in a pyritic form, and that all the other copper minerals are merely the result of secondary deposition.

Cornwall has furnished to the scientific world some of the most beautiful and interesting copper minerals that have ever been seen. The magnificent series of copper arseniates, cuprites, etc., which adorn our collections, are superior to anything of the kind yet discovered: gems from Nature's laboratory, and "by-products," if I may be allowed the expression, resulting from the process of secondary enrichment.

This natural process of secondary enrichment is not limited to copper ores, for we have ample evidence of the concentration or enrichment of gold and silver ores, at a point below what is termed the zone of oxidation, in pyritic gold-bearing lodes, the oxidation of the ore, the solution of the gold and silver, and the secondary deposition of the metals, at a greater depth, in contact with the mother mineral pyrites.

It is hardly desirable that I should attempt to discuss the theories which have been suggested by chemists and geologists to account for the changes referred to; full particulars may be found in recent papers on the subject.

The conditions which would seem to favour the enrichment of copper, gold, and silver, in veins, do not appear to apply to tin ores, and we can find no evidence of any process of enrichment from similar causes. Cassiterite, or native oxide of tin, is a particularly stable mineral, and is capable of resisting the solvent action of the solutions which are found to attack copper, gold, and silver. It is therefore probable, that so far as tin is concerned, we cannot suggest any theory of secondary enrichment with any hope of success. We have much evidence to prove that the

mineral, cassiterite, has been introduced into the veins and rocks by some agency at a period subsequent to their formation, by some solvent, the exact nature of which, up to this time, has not been satisfactorily explained. The boron and fluorine theories which may, or may not, hold good for Cornwall, cannot, I think, be accepted for certain other rich tin districts; as, for example, the Straits Settlements, and the mines of Bolivia, in which scarcely any evidence is found of the existence, in any well-marked quantities, of boron or fluorine.

In a general consideration of the subject of the genesis of ore deposits, scientists appear to be of one mind: they are unanimous in agreeing that such deposits are intimately connected with eruptive rocks.

There seems to be some difference of opinion, however, in regard to the agencies employed by nature in the solution of metals and their subsequent deposition in veins and rocks. Whilst Professors Posepny, Van Hise, Vogt, and others believe in deep-seated circulation of water, say at depths of 10,000 feet or more, Prof. J. F. Kemp, in his interesting paper, "The Role of Igneous Rocks in the Formation of Veins," suggests that the vapours, or dissociated gases, which occur so abundantly in molten rocks, will yield water on emission and cooling, and that it is probably water from this source which plays the part of a solvent of the metals at great depths.

It may be of some interest to members of this Society to know that a discovery has recently been made, by gentlemen connected with the Geological Survey, of tin in Ross in Scotland, and the conditions under which it occurs are somewhat peculiar. The rock is described as granite gneiss, and the tin is associated with magnetite, which is found in veins and streaks. One sample was found to contain from 15 to 17 per cent of cassiterite, and an analysis of another specimen containing 86 per cent of magnetic oxide of iron, gave 3·22 per cent of cassiterite.

Particulars of the occurrence of the tin may be found in the summary of progress of the Geological Survey of the United Kingdom for 1903, and an excellent suite of specimens is

exhibited at the Museum of Practical Geology, Jermyn Street, London.

The association of tin oxide with magnetite is exceedingly rare. I have only seen one other example, which was said to have been found near Ponsanooth. The Scotch specimens seem to have no connexion whatever with tourmaline, or in fact with any of the usual accompaniments of cassiterite.

It will be interesting to note the results of further developments by the Survey to discover to what extent the deposit may be considered of economic value.

I would like, by way of conclusion, to refer briefly to a subject which has interested me during my recent visits to Cornwall, viz. the gradual disappearance in depth, in certain of the tin veins, of pyritic minerals, sulphur-bearing minerals, such as pyrite and arsenopyrite. In my early experience of the more important mines in Cornwall, as for example Dolcoath and neighbouring mines, oxide of tin was almost invariably associated with more or less pyritic minerals, so that calcining was absolutely necessary at a certain stage in the process of tin dressing, and very large quantities of crude arsenic were collected and sold to arsenic refiners.

Through the kindness of the Manager of Dolcoath Mine, Mr. R. Arthur Thomas, I have been furnished with a series of vein specimens, about twenty in number, taken from depths ranging from 350 to 485 fathoms below the adit level or 380 to 510 fathoms below the surface. I have very carefully examined the different specimens of ore, and only in one instance could I discover the slightest evidence of pyrites, and that, curiously enough, was the piece taken from the greatest depth; 485-fathom level, and in this particular case I noticed three minute specks of iron pyrites, in a matrix which showed no tin.

A piece sent me at the same time, taken from the 210-fathom level, New Sump, is a typical specimen of the ore that was mined some forty or fifty years ago, and shows the presence of

chlorite, fluorite, with a pretty liberal sprinkling of arsenopyrite, "the White Mundic" of the miner.

I have thought that it would be interesting and instructive to go a step beyond the evidence adduced by these specimens, of the disappearance of pyrite in depth, and I have received from Mr. Thomas a sample of the first concentrates taken from the Frue vanners, as representing an average of the ore from the mine. The degree of concentration at this stage of the process of tin dressing, being about twenty tons of ore into one ton of concentrates. Assuming that the bulk of the pyritic mineral, if present in the ore, will be found in a concentrated form in the richer material, there should be no difficulty in determining, with a certain amount of accuracy, to what extent pyritic minerals exist in the average ore extracted from the mine at the present time.

A careful determination of the amount of sulphur in the concentrates shows that they contain 0·95 per cent sulphur, which represents 1·78 per cent of iron pyrite.

We have to make some allowance, however, for certain losses sustained in the concentration of the ore, and assuming a loss of one-half of the pyrites, which is probably largely in excess of the actual loss, we have the insignificant quantity of 0·178 per cent of iron pyrite existing in the general average of the ore which is mined for tin at this time.

If Dolcoath may be taken as a type of a Cornish tin mine, it would almost seem as if pyritic minerals, such as pyrite and arsenopyrite, are not found to any marked extent below a certain zone, say from 200 to 300 fathoms from the surface. It would be interesting to obtain further evidence on this subject from other mines, for it is only by a careful collection of facts that we can hope to solve some of the great problems connected with mineral deposition.

As some of these facts may be said to be somewhat at variance with the generally accepted theories of mineral formation at great depths, I have thought it perhaps sufficiently interesting to draw

attention to the matter, with the hope that some one, better capable than myself, would continue the investigation.

The late Sir Warrington Smyth, who was one of the keenest of observers of facts connected with mineral deposits, in his presidential address at a meeting of this Society, November 1st, 1899, in referring to the theories of Sandberger and others on the deposition of minerals, says:—

> "First of all I believe it may be safely held that the theoretical views on the origin of the tin deposits presented by Daubrée, are far more worthy of acceptation than any other hypothesis that has been brought forward, and that reference to this important mineral might be omitted except to remind you that its occurrence is inextricably mixed up with compounds of other metals with sulphur and arsenic."

The developments during the last two decades would indicate that metals combined with sulphur and usually associated with tin at comparatively shallow depths, wholly disappear at considerably deeper points, and whether this change may be taken as an indication of possible impoverishment of the veins, as greater depth is reached, so far as tin is concerned, is a matter of some importance to Cornwall, from a mining point of view.

REPORT OF THE COUNCIL

To the Annual General Meeting, 31 *October*, 1905.

DURING the past year the usual affairs of the Society have received the attention of the Council, who now have the pleasure to report to the members that the Society has continued its record of interest and usefulness for the ninety-second year of its existence.

The Society is indebted to the President and to Mr. H. Fox and other donors for several specimens of great interest and value which have been added to the mineral and fossil collections during the year, the particulars of which will be seen in the Report of the Curator.

The Council have decided to award the Gold Medal for this year to Lady Warington Smyth, in recognition of the great services rendered to this Society by the late Sir Warington Smyth, and are confident that their decision will meet with unanimous approval.

Sir Warington Smyth filled the office of President from 1871 until his death in 1890, with the exceptions 1880–1, 1881–2, 1882–3, and 1883–4; and throughout this long period the Society not only enjoyed the advantage of the annual presidential addresses which now enrich the pages of the *Transactions*, but also derived the benefit of his personal advice and assistance and the encouragement and distinction which his great reputation conferred.

In addition to the addresses which he delivered as President, the Society has the distinction of publishing several valuable papers which he contributed to the *Transactions*.

In view of all this help and work, and of the eminent position which the late Sir Warington Smyth so deservedly attained in the

scientific world, the Council are satisfied that they are completely carrying out the wishes of the donor of the medal and acting with the cordial approval of the members in asking Lady Smyth to accept the highest recognition which it is in their power to bestow, and one which would unquestionably have been first conferred upon our late respected President had the opportunity occurred in his lifetime.

The President's year of office continues until the next annual meeting. The Council recommend the re-election of the other officers and of the Council.

The Chairman presented the William Bolitho Gold Medal for 1905 to Lady Warington Smyth, who replied :—

Allow me to express my heartfelt thanks to the Council of the Royal Geological Society of Cornwall for their kindness in awarding to me the Bolitho Gold Medal of this year. I accept with pride their noble gift, by which they desire to do honour to the memory of Sir Warington Smyth, their President for as many as fifteen years.

The medal will ever speak to my sons and to myself of the regard which your Geological Society entertained for Sir Warington. And it will remind us too of the great regard Sir Warington bore the Society, and of the lively interest and pleasure he had in giving time and thought to his duties as your President. It was a truly genial task to him—and he felt the *bon camaraderie* of your Council. For he loved Cornwall; its granite moors, its tin-streamed valleys, its rocks and mines—he knew them well, for he had deeply studied them. And he loved his Cornish friends, and highly valued the great qualities characteristic of Cornishmen, their largeness of spirit and intellectual aspirations.

The outcome of these had been this Society, founded when geology was in its infancy, nearly one hundred years ago. Thus, while William Smith (the "Father of Geology") was preparing the first reliable map of "The Strata of England and Wales," published in 1815, your Geological Society of Cornwall had

already, in 1814, begun its work—started by your distinguished countryman, Mr. Davies Gilbert, President of the Royal Society, in concert with a few other kindred spirits. And so liberally was it supported, that in little over fifty years its funds sufficed to build this Institute, the home for Geology in Penzance, with its fine halls, the one adorned by your splendid collection of minerals and Cornish rocks, the other filled with a complete course of geological specimens, with its library and laboratories. Your *Transactions* being steadily printed meanwhile.

When Sir Warington comes upon the scene he finds the list of members and associates of your Society most interesting, including not only the names of the rich and influential men of the Duchy, with the Duke of Cornwall at their head, not only of men of science, but of poor men, the unlearned, the unobtrusive—and, too, of men of business and captains of mines. Ladies gave their aid and their influence, and here in Penzance the tradespeople (to their credit be it stated) willingly paid their guineas to enjoy their membership. "One and all" flocked to Penzance to hear the discourses of their presidents at the annual meetings.

Zeal of this kind met a quick response from Sir Warington. He was in special sympathy with your members, for are not all Cornishmen born miners, inheriting, from distant ages, an instinctive love for "the Bal"? And had not Sir Warington, from his Cambridge days, been a devoted student of the scientific art of mining?

At the commencement of his career Sir Warington had been received at Berlin by those great geologists Alexander von Humboldt, Von Buch, and Von Dechen; thence he went on to study at the Mining Schools of Saxony and Hungary, and, in subsequent years, he went down, I may say, every noted mine in Europe, whilst he enjoyed still closer intimacy with British mines, and the specially interesting rocks of Cornwall, visiting your mines and pursuing their ore-laden lodes to their deepest levels year by year.

No wonder then, that he was in harmony with the aims and the spirit of your Society during the past century.

Meanwhile, in one of the least important of your mines,

situate in the heart of Cornwall, was locked up a mystery of vast importance for the philosophers of science.

The small Uranium mine near Probus was well known to Sir Warington; from it he had obtained even finer specimens of the beautiful Green Uranite and the unattractive Pitchblende than those he brought from Joachimsthal.

In 1902 Sir William Crookes visited the mine, deeply interested in carrying out in his own laboratory the most delicate and searching analysis of these ores.

Becquerel had already in 1896 gone far to show some marvellous qualities in Uranium (of emitting emanations); but only with the new century was the great secret to be divulged, and in 1903 the brilliant researches of M. and Madame Curie were crowned by the discovery of Radium.

In Sir William Crookes' first paper on Radium, delivered to the Congress of Applied Science at Berlin, June 5th, 1903, there is a paragraph of exceptional interest to Cornishmen and especially to the people of Penzance. He calls the paper "The Realization of a Dream," and points out that among the men of science of the past century devoted to speculating as to the origin of matter, of units and atoms of electricity, we find a genius here and there capable of dreaming of the undiscovered possible. He quotes Sir Humphry Davy as the first of these philosophers to give expression to such a dream in a lecture to the Royal Institution in 1809. In that memorable lecture

> "he speculated on the existence of some substance common to all the metals, and he averred that 'if such generalizations should be supported by facts, a new, a simple, and a grand philosophy would be the result. From the combination of different quantities of two or three species of ponderable matter we might conceive all the diversity of material substances to owe their constitution.' Again in 1811 he said, 'It will be useless to speculate upon the consequences of such an advancement in chemistry as that of decomposition and composition of the metals. . . . To inquire whether the metals be capable of being decomposed and composed is a grand object of true philosophy.' Davy first used the term 'Radiant

Matter' about 1809, but chiefly in connexion with what is now called radiation. He also used the term in another sense, and the following passage, in its clear forecast, is prophetic of the modern electron: 'If particles of gases were made to move in free space with an almost infinitely great velocity—i.e. to become radiant matter—they might produce the different species of rays, so distinguished by their peculiar effects.'"

Thus are the centuries linked together by chains of prophetic thought, and Sir Warington took his place in this dreamland among the deep thinkers on these mysteries. His knowledge of the attributes of minerals was intimate and vast; and we cannot doubt that his observant mind, with its innate love and sympathy with Nature, was one of those which are, in Sir Wm. Crookes' words, "capable of dreaming of the undiscovered possible."

I take it to be in recognition of this that your Society dedicates to his memory their beautiful medal of 1905, which his sons and I receive so gratefully.

LIBRARIAN'S REPORT.

1905.

THE Librarian acknowledges, with thanks, the receipt of publications from the following:—

American Philosophical Society.
—— Academy of Arts and Sciences.
—— Geographical Society.
Australasian Association for the advancement of the Sciences.
Batavia. Jaarbock.
Belgium. Société Royale Geologique.
Bristol Naturalists' Society.
British Association.
Buenos Aires. Museo Nacional.
Canada. Geological Survey.
——. Royal Society.
Canadian Record of Science.
Cape of Good Hope. Geological Commission.
Colorado Scientific Society.
—— College Studies.
Cornwall Royal Institution.
—— Royal Polytechnic Society.
Denmark. Dansk Geologisk Forening.
Dorpat. Naturforscher Gesellschaft bei der Universitat Jurjew.
Dublin Royal Society.
Elisha Mitchell Scientific Society.
Geological Survey.
Geological Society.
Geologists' Association.
India. Geological Survey.

Indiana. Academy of Science.
Iowa. Geological Survey.
Japan. College of Science of the Imperial University of Tokyo.
Leicester Literary and Philosophical Society.
Liverpool Literary and Philosophical Society.
—— Geological Society.
London and West Country Chamber of Mines.
Manchester Geological Society.
—— Geographical Society.
Maryland Geological Survey.
Mexico. Instituto Geológico.
Michigan Academy of Arts and Sciences.
Monte Video. Museo Nacional.
Museums' Journal.
Natal. Geological Survey.
New York Academy of Sciences.
New Zealand. Department of Mines.
New South Wales. Geological Survey.
North of England Institute of Mechanical and Mining Engineers.
Peru. Cuerpo des Ingeniores de Minas.
Philadelphia. Academy of Natural Sciences.
Plymouth Institution.
Queensland Government.
Royal Society.
Saxony. Berg und Huttenwesen.
Smithsonian Institution.
South Australian School of Mines.
Tuscany. Societa di Scienzi Naturali.
United States. Geological Survey.
Upsala. Geological Institution.
Vienna. K. K. Geologischen Reichsanstalt.
Victoria. Department of Mines.
Western Australia. Geological Survey.
Wisconsin Academy.

[*From the Authors.*]

The Island of Ictis. By Clement Reid, F.R.S.

Tin Deposits of the World. By S. Fawns, F.G.S.

The Relations of Geology. By C. Lapworth, LL.D., F.R.S.

The Foraminifera of the Malay Archipelago. Part 10. By Fortescue W. Millett, F.R.M.S.

[*Purchased.*]

Palæontographical Society. Vol. lviii.

London, Edinburgh, and Dublin Philosophical Magazine.

CURATOR'S REPORT.

DONATIONS TO THE MUSEUM.

By HOWARD FOX, F.G.S. :—

CRUSTACEA.

OSTRACODA.

Entomis serratostriata. From Trevanger Hill Quarry.
„ *gyrata* ? From Rooke Mill Quarry.
„ sp. „ „ „
Barychilina ? *semen.* Sandb. do. (figured and described by Prof. Rupert Jones, *Ann. and Mag. Nat. Hist. Soc.*, Vol. XV, Pl. VII, 5*a*, 5*b*).

TRILOBITA.

No. 1. *Phacops latifrons.* From Cant Hill. (Pl. I, figs. 1*a*, 1*b*, 2 ?)
„ 2. „ (*latifrons* ?) „ „ (Pl. I, fig. 2.)
„ 3. „ *granulatus.* From east of Cant Cove. (Pl. I, figs. 3, 4.)
„ 4. „ „ From Cant Hill.
„ 5. „ „ „ „
„ 6. „ (*latifrons* ?) „ „
„ 7. „ *punctatus* „ „
„ 8. „ *lævis* (?) „ „
„ 9. „ *latifrons*, eye of. „ „

CEPHALOPODA.

Orthoceras cf. *hercynicum.* (Pl. I, figs. 6*a*, 6*b*.) East of Cant Hill.
„ cf. *commutatum.* (Text figs. 1, 1*a*, p. 65). Cant Hill.

Pragmoceras (?) sp. (Pl. I, fig. 7.) Cant Hill.

Agoniatites sp. (Text figs. 2, 2*a*, p. 69). Cant Hill.

Orthoceras longicameratum, Foord (= *O. commutatum*, Giebel). From east of Dinham Creek.

Orthoceras (intermediate between Rœmer's *O. rapæforme* and *O. subconicum*). From east of Dinham Creek.

Orthoceras nassoviense, Foord (= *O. commutatum*, Giebel). Near Trewornan.

Orthoceras gracile. From near Trewornan.

Bactrites ? Fragment. „ „

Bactrites ?
Orthoceras ? } From Gravel Cavern Conglomerate.
Tornoceras ?

Goniatites ? From Trevone, Booby's Bay, etc.

BRACHIOPODA.

Orthothetes crenistria (?) Fragment from Cant Hill.

Orthothetes (?) Of peculiar character. From Cant Hill.

Atrypa reticularis. Well preserved „ „

Atrypa, cf. *desquamata*. With peculiar ridges. From Cant Hill. Several specimens.

Spirifer sp. Apparently new species. From Cant Hill.

Spirifer sp., cf. *speciosa*. From Cant Hill.

Pentamerus (? *Gypidula*) *brevirostris*. From Cant Hill.

Rhynconella (*Camarotœchia*) *laticosta* ? var. From Cant Hill.

LAMELLIBRANCHIATA.

Posidonomya venusta. From Rooke Mill Quarry, St. Kew.

„ „ sp. „ „

Cardiola retrostriata. Several specimens from Gravel Caverns Conglomerate, Booby Bay, Trevone, etc.

PTEROPODA.

Styliola sp. From Epphaven, Porthilly Cove, east and west of Dinham Creek, Harbour Cove Padstow, etc.

Conularia subparallela. Cant Hill.

Conularia sp., cf. *C. deflexicosta*. Porthilly, Cant Hill.

ACTINOZOA.

Petraia spp. Common.
Zaphrentis sp. Common.
Amplexus (?) sp. Cant Hill
Cyathophyllum sp. Rare. Cant Hill.
Favosites sp. Cant Hill.
Alveolites sp. Common. Cant Hill.
Pachypora sp. *a*. West of Com Head.
Pachypora sp. *b*. Gravel Caverns Conglomerate.
Pleurodictyum sp. Common.
Cladochonus sp. Cant Hill.

POLYZOA.

Monticulipora (Monotrypa) sp. Cant Hill.
Fenestella sp. (*a*). Cant Hill.
Fenestella sp. (*b*). ,,
Polypora sp. East of Cant Cove.
Phyllopora sp. Cant Hill.

By B. KITTO, F.G.S. :—
"Triplite." From Lingar Gaya District, India.
'Tantalite." From South Australia.

By R. PEARCE, F.G.S. :—
Breccia cemented by Tin Oxide and Tourmaline. Bolivia.
Breccia cemented by Tin Oxide. Bolivia.
Quartz Porphyry, containing Pseudomorphs of Tin Oxide after Felspar. Bolivia.
Waterworn Pebbles of Quartzite impregnated with Tin Oxide.
Tin Pseudomorphs from Bolivia.

TREASURER'S STATEMENT, 1905.

Dr. *The Treasurer in Account with the Royal Geological Society of Cornwall.* **Cr.**

Receipts.

October 31st, 1905—	£	s.	d.
To Ordinary Subscriptions	50	8	0
,, Subscription per His Royal Highness the Prince of Wales	20	0	0
,, One Year's Dividend on £1800 Midland Railway 2½% Debenture Stock, £45 0*s.* 0*d.*, tax £2 5*s.* 0*d.*	42	15	0
,, Sale of *Transactions*	1	16	8
	£114	19	8
,, Balance due to Treasurer	10	11	5
	£125	11	1

Expenditure.

October 31st, 1905—	£	s.	d.
By Balance from last year's Account	34	2	2
,, Rates and Taxes	0	8	0
,, Curator's Salary	42	15	0
,, *Transactions*, Periodicals, etc.	30	3	9
,, Fire Insurance Premium	2	12	9
,, Coals and Gas	8	19	11
,, Sundry Repairs to Buildings	1	9	7
,, Palæontographical Society (two years)	2	2	0
,, Postages, Carriage, Parcels, and petty disbursements	2	17	11
	£125	11	1
,, Balance due to Treasurer	10	11	5

PENZANCE, *October 31st*, 1905.

T. R. BOLITHO, *Treasurer.*

W. BOLITHO GOLD MEDAL ACCOUNT.

Dr.	£	s.	d.	Cr.	£	s.	d.
April 19th, 1905—				October 25th, 1904—			
To Garrard and Co.	12	10	0	By Balance	528	1	8
October 31st, 1905—				October 31st, 1905—			
Balance	528	15	8	By Interest on Account	13	4	0
	£541	5	8		£541	5	8
				By Balance	528	15	8

LIST OF PAPERS

READ TO AND PUBLISHED BY THE SOCIETY.

1904.

President's Address. By Dr. R. Pearce, F.G.S.

The Variegated Slates of North Cornwall. By Howard Fox, F.G.S.

The Earth-Cliffs at Godrevy. By Rev. D. Gath Whitley.

Pseudomorphs of Oxide of Tin from Bolivia. By Dr. R. Pearce, F.G.S.

THE VARIEGATED SLATES OF NORTH CORNWALL.

By Howard Fox, F.G.S.

(Read 31 October, 1905.)

Among the most striking features of some parts of the scenery of North Cornwall are the "variegated slates" formed of purple, green, buff, grey, and blue beds, banded and ribboned in quite a brilliant manner. They are most conspicuous in the parishes of Padstow, St. Minver, and St. Kew. These beds have been frequently referred to by writers on Cornish Geology. Slates of similar colour and texture are seen in Watergate Bay, north of Newquay, and between Fowey and Looe on the south coast, containing fossil fish-remains typical of Lower Devonian rocks. There is also a small zone of purple and green slates in the Falmouth beds, which is conspicuous in the eastern side of the upper end of No. 2 Graving Dock, as also in the foreshore and cliffs under the west side of St. Mawes Castle; but hitherto these Falmouth slates have yielded no fossils.

The variegated slates of Padstow, St. Minver, and St. Kew were also, until lately, considered to be unfossiliferous.

Dr. Henry Boase read papers to your Society in 1830 and 1831,[1] in which we read at page 198 of your fourth volume: "From Rock House to Trebetherick, about half a mile north of St. Enodock, the country consists of immense sandhills; at this village slate again appears, and may be traced along the cliffs to Pentire Point. . . . The most abundant kind is of a dark reddish brown, which is frequently intermixed with greenish and yellowish grey beds; indeed all these are often blended together in patches, spots, and stripes." At page 257 he writes: "In the neighbourhood of Harbour Cove (a little creek on the western side of Padstow Harbour) the cliffs consist of the same red slate already noticed on the opposite side."

Sir Henry de la Beche published his Report on the Geology of Cornwall in 1839. At page 88 he speaks of "a mass of variegated slates extending across the country from St. Kew and St. Minver to Padstow Harbour." At page 91 we read: "the red and variegated beds of St. Kew and St. Minver seem to be the same with the red and variegated beds of Watergate Bay." He could not have fallen into this error if he had been aware of the fossil evidence we now have before us. It is an interesting coincidence that rocks of widely different ages should have been deposited under such similar

[1] *Trans. Roy. Geol. Soc. Corn.*, vol. iv. pp. 167–474.

natural conditions as to form these striking variations of brilliant colours.

In your sixth volume of *Transactions* (pp. 132–3) the Rev. David Williams describes these beds as an "enormously thick bed of slates, strongly characterised as green, blue, purple, and grey (the purple chiefly prevailing), in almost endless alternation . . . abundant facilities of identifying and observing their striking peculiarities as contrasted with all or either of the others, are afforded more especially by the cliffs on either side of the Tamar, from Plymouth up to near Pentilly Castle on the eastern region, and the shores of the Padstow estuary on the west, from Wadebridge to Stepper and Pentire Points at its mouth."

Mr. Williams records on the same page having "collected along the north shore of the Padstow river a greater abundance of the same *trilobites*, *molluscs*, *corals*, and *crinoides*, than I had gathered among the same grey calcareous slates in the same relative position near Plymouth" (*id.* p. 132).

In the paper I read to you last year on the fossils of St. Minver I entirely overlooked this record of Mr. Williams' discovery. In another passage he writes: "the upper grey calcareous beds . . . conceal all the subordinate variegated beds until between St. Mabyn and St. Tudy a higher angle brings up the blue, purple, green, and grey slates which range continuously from thence by Endellion, St. Minver, and St. Enodock in a thick zone to the north and west of Padstow" (*id.* p. 135).

By a curious perversity of judgment this industrious but eccentric observer contended that these variegated slates were deposited on the top of the Tintagel slates. Sir Roderick Murchison, at page 323 of your sixth volume, refers to this eccentricity thus: "I doubt however if anything I have stated will make an impression upon my good-humoured antagonist the Rev. D. Williams, whose views of the Cornish succession of strata seem to be opposed to those of all his contemporaries."

In the paper published in your *Transactions* last year on "The Fossils of St. Minver" Mr. Ussher says (p. 86): "The variegated purple and green slates of St. Kew and St. Minver . . . are well represented between Liskeard and Plymouth, and contain *Entomis* and *Styliola* and also *Tentaculites*. *Entomis* has not yet been certainly identified on the north coast, but *Styliola* and small *Tentaculites* were obtained by us in the cliff of Butter Cove, near Stepper Point, in the purple and green slates."

It therefore was only reasonable to expect that the variegated slates on the opposite side of Padstow Bay and Harbour, if carefully searched, would be found to contain organic remains. During last month I was able to prove this to be the case. I did not happen to find a single fossil weathering out or visible on the surface of the slates, so that

'ı I examined the cliffs, foreshores, most of

ı ny of the roadside and other

ı of St. Kew and St. Minver,

to hit on every fossiliferous

horizon. I was also successful in finding *Styliola*, *Tentaculites*, *Ostracoda*, and other minute organisms in the variegated slates north of Padstow, viz. on both sides of Harbour Cove, and further on towards Stepper Point, until the igneous rock monopolizes the coast. The following localities in the parishes of St. Minver and St. Kew proved fossiliferous:—

ST. MINVER.

1. *Trestram Cove Cliff.*—The slates forming the upper part of the low cliff commencing about 300 yards west of Polzeath House are easily accessible either from below or above, and those adjacent, which surround Trestram Cove contain horizons crowded with minute *Ostracoda* (small bivalve crustaceans resembling water-fleas). To the naked eye these little organisms appear like spots of rust, but a lens shows them to be casts of oval bodies from 1 mm. in length upwards. Some of them are species of *Entomis*. A single square inch of surface will occasionally show from 80 to 100 of these casts. This productive horizon can be traced in places for several hundred yards further east towards Greenaway.

One specimen of grey slate from this district was full of scales of green carbonate of copper. The question may arise whether the green colouring of these slates cannot in part owe its origin to the diffusion of this metal.

I found that if the sound of the hammer on these slates was dead and dull it was useless to expect

By a curious perversity of judgment this industrious but eccentric observer contended that these variegated slates were deposited on the top of the Tintagel slates. Sir Roderick Murchison, at page 323 of your sixth volume, refers to this eccentricity thus: "I doubt however if anything I have stated will make an impression upon my good-humoured antagonist the Rev. D. Williams, whose views of the Cornish succession of strata seem to be opposed to those of all his contemporaries."

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such slates to contain organic remains, but when the sound was sharp, success would often reward the search. The more sandy the composition of the slate the better was the chance of finding fossils.

2. *Shilla Mill.*—The quarries and other sections between Polzeath Cottage and Shilla Mill expose purple and green slates, which occasionally contain casts of *Ostracoda*, etc.

3. *Tredrizzick Hill.*—The next fossiliferous horizon is about two miles south-east of Polzeath on either side the high road, in the hill leading from Pityme to Tredrizzick, where purple slates contain numerous *Ostracoda.*

4. *Trevanger Hill.*—A quarry has been opened by the side of the public road in this hill, about 600 yards west of St. Minver Church. The slate here is pale greenish brown and contains *Ostracoda*, fragments of *Posidonomya venusta*, and other shells, many of them showing excellent structure. Mr. Ussher recognized *Entomis serratostriata* among them.

The purple slates on the west side of this road are also, in places, full of fossil *Ostracoda.*

ST. KEW.

5. In this parish the village of Chapel Amble is built on the bare surface of variegated slates, the parallel bedding of the purple and pale grey beds being a conspicuous feature of a large open space on either side of the highway. The elbow of a

large fold is plainly seen in the upper part of the village in this open space on the east side of the highway.

Styliola and other organisms are seen in the edges of these beds on the east side of the road, and again by the side of the road leading out of the village north of Amble just in front of a cottage on the east side of the road.

6. Similar organisms are found in the village of St. Kew in purple slates on the south side of the highway, 150 yards north of the church.

7. At Rooke Mill Quarry, 1200 yards north of Chapel Amble, purple slates are being quarried. These slates contain numerous *Ostracoda* and bivalve shells and fragments, many of which show excellent structure. The most frequent shells are those of *Posidonomya venusta*, some of which are about one inch in length. Among the *Ostracoda*, *Entomis serratostriata* and *E. gyrata* (?) are the most frequent organisms. *Barychilina* (?) *semen*, Sandb.,[1] was also found here.

I am indebted to Mr. Ussher for the identification of the above species. He classes them as Upper Devonian fossils, and characteristic of the Cypridinen-schiefer of Germany.

The specimens now placed in your museum represent most of the forms met with up to this day.

[1] Identified by comparison with the figure by Professor Rupert Jones, *Ann. and Mag. Nat. Hist. Soc.*, vol. xv., Pl. VII, 5*a*, 5*b*.

Mr. Ussher has sent the various organisms and submitted his identifications to his friend Dr. Kayser, of Marburg, whose report will, I hope, be printed at foot.

Since the foregoing was in the press Mr. Ussher has received a letter from Dr. Kayser, who writes as follows, dated 4 January, 1906 :—

"The holidays have given me at last the opportunity of examining more carefully the specimens collected by Mr. Howard Fox, and sent me some weeks ago. Not the slightest doubt can remain as to the Upper Devonian age, or the fact that the fossils belong to the Cypridinen-schiefer. They might easily have come from the Dillenburg, so close is the geological resemblance of the slates to those of the Upper Devonian Rhine.

"I have found among the material sent me—besides undeterminable remains which come perhaps from Trilobites—nothing but *Posidonia venusta* and *Entomis serratostriata* which are just the two chief characteristic and widely-spread forms of the Cypridinen-schiefer. At the first glance, it is true, you think you have other species among them; but closer observation shows that you only have to do with fragments of *Posidonia venusta*, very much crushed and deformed by pressure.

"Cypridinen or *Entomis serratostriata* shows itself with clearly recognizable striation in the typical bean-shaped and moulded modification as given by Prof. Rupert Jones (*Ann. and Mag. Nat. Hist. Soc.*, 1895, s. 6, vol. xv. fig. 6*a*, 6*b*)."

THE EARTH-CLIFFS AT GODREVY.

By Rev. D. Gath Whitley.

The phenomena of Waste, so important in the eyes of the geologist, can be studied with great advantage in Cornwall. Our remarkable climate and our almost insular position combine to present the decay and degradation of rocks in a most striking manner. Our heavy and continuous rainfall fills our inland basins with alluvial débris, and the miniature beds of clay, sand, and gravel, which choke the clefts and gutters by the side of our roads on the hills, show to the beginner in geology how similar deposits, on a far greater scale, may have been formed. The incessant roll of the billows against our cliffs, aided by their degradation by frost and rain, constantly, though almost imperceptibly, produces changes, even on our "iron-bound" shores. But there are some parts of the Cornish coast where the cliffs are composed of such soft and loose materials that their decay is extremely rapid, and where sub-aërial waste proceeds very quickly. In no place on our shores can these changes in loose friable cliffs be better observed than on the eastern side of St. Ives Bay.

The line of cliffs which extends from Godrevy

Island on the north, to the mouth of the Red River on the south, presents some very interesting features to the geologist. For a distance of a mile—measuring around the curves of the coast—the cliffs are formed of loose earthy materials which are subject to rapid denudation. At the foot of the cliffs, sometimes in close contact with the present beach, and sometimes resting on blue slate rock, appears an old Raised Beach. It is of the usual character, presenting small *rounded* pebbles and oval flattened pieces of quartz and slate which are perfectly smoothed. These pebbles are embedded in a matrix, which has been firmly consolidated. The thickness of the Raised Beach varies. It is generally only a thread of small pebbles, less than a foot in thickness, but it is sometimes several feet in depth. Above the Raised Beach is a mass of red earthy rubble full of angular fragments of quartz, which are heaped together in utter confusion, and lie at all angles. This deposit—which is often more than thirty feet thick—is known as "the Head of Rubble," or more briefly, "the Head." It is the most important of all the Quaternary deposits in Cornwall, and the one which can best be studied. The dividing line between it and the Raised Beach is always sharply defined and perfectly distinct, so that there is no gradual transition from one deposit to the other. Besides these two beds, the earth-cliffs at Godrevy contain a *third* formation. This consists of consolidated sand. This is only occasionally present, but it is sometimes ten feet or more in thickness, and where the three deposits

occur, the sand occupies the middle position, between the Raised Beach beneath and the Head above. There are therefore in the earth-cliffs at Godrevy *three* divisions: the Raised Beach, the Sand, and the Head. Of these the Head is by far the most important, and the Raised Beach is the smallest.

The earliest geological account of the earth-cliffs at Godrevy with which I am acquainted is that given by Dr. Boase, whose observations are recorded in the *Transactions* of this Society. As his account was written more than eighty years ago, it is extremely instructive, and I will give it in his own words. He says:—

"The cliffs at Godrevy afford another example of the diluvial deposit so common on our shores. A ferruginous clay with angular fragments of rock imbedded therein, forms a bed of twenty feet in thickness. The angular pieces are of the same nature as the hill above, which proves that this diluvium has not been transported to any great distance. Beneath this is a bed of rounded pebbles and gravel, many parts of which are consolidated; and some idea of the tenacity of this rock may be formed when it is stated that a detached mass (about eighteen feet long, twelve wide, and three in thickness) rests across the basset edges of the strata in the form of a lintel, or the upper stone of a cromlech; the opening beneath is five feet on the one side and nearly ten feet on the other. In tracing this diluvium eastward, it will be observed to diminish in thickness as the land rises; so that it is

not a foot deep on the summit of those cliffs that are formed by a section in the highest part of the hill."[1]

It will be noticed that in this description, Dr. Boase distinguishes between the Raised Beach and the Head which lies above, accurately stating the prominent features of both deposits. He does not call them by their modern names, and uses the term *diluvium* for them both, a phrase which, though out of date in England, is still largely used on the Continent, particularly in France. The detached mass covering an isolated block of slate on the beach, and said by Dr. Boase to resemble a cromlech, can easily be found. It is a firmly consolidated mass of sand, forming a complete cap to a slate rock, which lies about seventy yards from the cliff. The sand of this capping is full of flattened and oval fragments of slate and quartz, which are perfectly smooth and rounded and precisely similar to those in the Raised Beach, but totally different from the angular fragments of the Head. The crevices in this detached slate rock are filled with the consolidated sand, which is as hard and compact as cement. Doubtless the capping has suffered a measure of waste since Dr. Boase visited it, but his description of it is even now quite correct.

Mr. W. A. Ussher has also described the Godrevy earth-cliffs,[2] and has given a valuable drawing of

[1] *Trans. Roy. Geol. Soc. Corn.*, vol. iv. pp. 309, 310.

[2] In his valuable work entitled *The Post-Tertiary Geology of Cornwall.*

them in section, which marks the distinction between the Raised Beach and the overlying Head.

More than twelve years ago Sir Joseph Prestwich wrote a most lengthy and valuable treatise on the Superficial Deposits formed at the end of the Palœolithic Period, which he called "The Rubble Drift." In this paper he described some Cornish Quaternary formations, amongst which were the Godrevy earth-cliffs, which he considered to be of the same age as the beds of sand and clay at St. Agnes' Beacon and our stream-tin beds.[1] He also gave a diagram which represented an isolated pillar rising on the beach, about seventy yards from the cliff. This pillar was formed of four distinct divisions. At the bottom was the slate rock; next above it came a fragment of the Raised Beach; then consolidated sand; and lastly, on the top, genuine Head. Dotted lines in the diagram connected this pillar with the cliffs behind, in which the same *four-fold* division was presumed to exist. I have searched Godrevy beach carefully, but have been unable to find this pillar. There is but *one* kind of capping to the "cromlech," as Dr. Boase calls it, which looked at from the end might perhaps be thought to resemble a pillar. This capping is entirely formed of hardened sand, and contains flattened and *rounded* oval pebbles of quartz and slate, which are precisely similar to those found in the Raised Beach, and are entirely different from the

[1] *Quarterly Journal of the Geological Society of Great Britain*, vol. xlviii. p. 281.

angular fragments of quartz which are found in the genuine Head.

My own observations, made during several visits to Godrevy, I will summarize as follows:—

The earthy cliff or Head is of variable thickness, and of a pale brown colour. In some places it has been worn back so that it presents a long slope, furrowed deeply with water-channels by the rain courses. Here and there great earthy pinnacles stand up in the Head, and reach a height of from seven to eight feet. These pinnacles are marked by long lines of shattered quartz which often present a regular linear arrangement, but frequently are piled up irregularly. At the foot of the Head, the Raised Beach is on an average from one foot to one foot six inches in thickness. The denudation of the Head proceeds rapidly under atmospheric agencies, great earthy masses of the Head being rolled down upon the beach, where their disintegration proceeds with great rapidity. Large portions of the beach, extending from fifty to a hundred yards or more from the foot of the cliffs seawards, are marked with earthy detritus, showing how the Head has been worn steadily backwards, and indicating its former greater extension towards the sea. This decay of the Head can be traced by the sloping banks of earthy rubble piled up at the bottom of the cliffs, and resting against their faces. At the top of the cliffs a series of perpendicular cracks can be observed penetrating the soil, at a few feet back from the edge of the cliff. These indicate how the agencies of water and frost

are constantly detaching large earthy masses from the upper face of the cliffs, which rolling down lodge on the beach below, forming a sloping earthy bank, often overgrown by grass.

Although the Raised Beach is generally only a foot or so in thickness this is sometimes exceeded, and at times it appears as a band several feet thick or more. The quartz and slate pebbles in it are oval, smoothed, and flattened, and generally of a uniformed character. The aspect of this Raised Beach is so strikingly different from the dark brown Head which rises in a cliff thirty feet above it, that the contrast is most striking.

The arrangement of the stony fragments in the Head is very instructive. These, so far as I have been able to observe, are all of quartz. They are shattered and angular quite different from the rounded, flattened, and smoothed oval pebbles in the Raised Beach. The quartz fragments in the head are of all sizes, and lie at all angles, and are often in small lines, and in some places of the Head they occur in masses and bunches, as though they had at these places been piled up by sudden and violent rushes of water. The size of these quartz masses in the Head is often great, many of them being several feet square, but on the beach below, the quartz boulders which were originally in the earthy cliff, and which have rolled down the slope, owing to the disintegration of the Head, are of much greater size. The quartz fragments in the Head are often in greater quantities at the top of

the deposit than at the bottom, but no definite rule can be observed in their arrangement.

The former sea-ward extension of the Head is very instructively exhibited. Earthy layers and detritus form the floor of the beach for a long distance beyond the foot of the earthy cliff. Also great boulders of quartz, often larger than a man's head, lie on the beach for a distance of nearly a hundred yards from the foot of the cliff. These were evidently in the Head, and when the seaward part of that deposit was denuded they were left lying on the beach, and have had their angles rubbed off by the incessant attrition to which they have been subjected by the action of the waves.

Although not able to take accurate measurements, I should consider that in some places the extreme height of the Head alone would not fall very far short of forty feet.

Proceeding northwards along the beach towards Godrevy Lighthouse, an interesting change in the formation of the cliffs becomes visible. Thick masses of consolidated sand, often twenty feet thick, lie over the Raised Beach, and are intercalated between it and the Head. The sand is in places so firmly consolidated that it lies in blocks, forming great cubes on the beach, for a time when it is detached from the bed and falls on the beach beneath. The presence of consolidated sand over a Raised Beach is a very common phenomenon on the Cornish coast, but I have never seen so instructive an illustration of it as at Godrevy. A little beyond

the Tea House towards the Lighthouse a most interesting section is exposed. At the top immediately beneath the vegetable mould is the Head, which is ten feet thick. Beneath this comes about ten feet more of hardened and consolidated sand. Underneath again lies the Raised Beach, which is here several feet in thickness, and beneath this, immediately in contact with the present beach, is the slate rock, about six feet of which is exposed.

The slate block on the beach which Dr. Boase likens to a cromlech is entirely capped by this hardened sand, which in some places has penetrated into the interstices of the slate and has hardened there. The upper surface of the sand capping of this block is worn into hollows and furrows by the action of the rain, but the general surface is flat like a table. The pebbles in this sand cap are all of quartz and slate, and are oval, flattened, and smoothed, being exactly like those in the Raised Beach immediately behind this block. The cliff, which is about seventy yards distant, contains but little Head or Raised Beach. Further on towards the north, that is towards Godrevy Island and Lighthouse, the Raised Beach, Head, and consolidated sand disappear, and the slate rock, in which the strata are highly contorted, takes their place.

The Head is thickest at the entrance of a small valley, but it extends to a considerable distance to the north and south of the opening. Mr. F. J. Thomas of Camborne has this year found a flint

from two to three inches long and about two inches broad in the Godrevy Head. It looks much like a scraper, but I cannot say definitely if it is of artificial origin.

About three quarters of a mile to the south of the mouth of the Red River the Raised Beach is also well seen. It is about four feet thick, and full of well-rounded pebbles of quartz. It rests on blue slate rocks, and its bottom is at least fifteen feet above the present beach; precisely in the same manner the Raised Beach at Fistral Bay at Newquay is much higher at the southern than at the northern end of the beach. The Head above this southern part of the Godrevy Raised Beach is from ten to fifteen feet thick, with *small* stones.

Such are the main facts of this interesting deposit: how are they to be explained?

I know that it is much easier to criticize the theories of others than to bring forward a satisfactory hypothesis oneself, and I fear that I cannot do much to solve the mystery of the origin of the Head.

We ought to bear in mind that whatever theory we advance to explain the formation of the Head, it should be able to account for three great facts relating to this deposit. *First*, it should take notice of the former greater extension of the Head seawards. *Secondly*, it should provide a cause sufficiently powerful to move the great blocks of quartz which lie in the Head and on the beach where the Head which originally surrounded them

has been washed away. These blocks are often from four to five feet square. *Thirdly*, any theory which professes to explain the origin of the Head must harmonize with the physical character and conditions of Godrevy Point.

Nothing like the Head is being formed on the coasts of Cornwall now. The present slight rainfall does not *deposit* rubble, but merely *denudes* the cliff, and washes channels and gutters in the sloping front of the Head. River action is out of the question, as in the limited area of Godrevy Headland there are no streams, and the Red River is too far off, and is of too insignificant a character, to be taken into account.

Professor J. A. Geikie tells us[1] that deposits resembling the Head are now forming in the Rocky Mountains. He gives us, however, no references, and as the Rocky Mountains are thousands of miles in extent, and present different features in different regions, the statement does not give us much assistance.

It is often declared that the Head on our Cornish coasts is a "glacial" deposit; but the phrase is ambiguous, and needs to be carefully defined. It has been said that when Cuvier, in arranging his scheme of zöological classification, marked off his sub-kingdom Radiata, he treated it as a kind of lumber-drawer, into which he consigned every organism the proper place of which in zoology he could not determine. Far be it from me to criticize

[1] *Prehistoric Europe*, p. 226.

the great naturalist, whose little finger was, I suspect, considerably thicker than the loins of many of his modern critics. I would, nevertheless, venture to make a respectful protest against the too frequent use of the term "glacial." The word is so vague that it may be understood in different senses. It may imply that a deposit was formed under glacial conditions; or it may mean that the deposit was formed during the Glacial Period. As the Great Ice Age is differently defined and understood, and as it is complicated by the introduction of Inter-Glacial Periods, the intricacy of the problem is much increased by the use of such an ambiguous term. I am not acquainted with any *direct* evidence to prove that the Head is of glacial origin, and I should much like to know if any pebbles bearing glacial scratches or markings have been found in the Quaternary beds on the Cornish coast. I have not heard of any. The promontory of Godrevy is too small to give rise to a glacier, for its extent is so limited that is does not provide sufficient area for a snow-field large enough to originate a glacier. Another theory is, that the Head was formed by torrents of water set free from the melting of the snow in the Glacial Period. These waters, discharging themselves in the summer, rushed down over the frozen soil in great volume, shooting over the depression great masses of earthy rubble, which thus formed the Head. This theory does not provide a force sufficiently powerful to carry along the great blocks of quartz, which are

several feet square in the Head. The melting of the snow would be a gradual process, taking place slowly, so that the water would trickle away in gentle streams; thus the water set free would not be powerful enough to form such a tumultuous deposit as the Head. The limited area, also, of Godrevy Point would not provide sufficient space for a snow-bed large enough to furnish the necessary amount of water when it melted. We cannot remove this difficulty by comparing Cornwall with the *present* state of the coast of Siberia, for the permanently frozen soil on the shores of the Arctic Ocean in this region is separated from the vegetable mould on the top of the cliffs by a thick earthy layer, a large portion of which is thawed every summer, at the time of the melting of the snow on the surface of the ground.

Nevertheless, the northern shores of Siberia, which face the Arctic Ocean, can, I believe, furnish us with interesting facts, which may throw some light on the origin of our Cornish "Head of Rubble."

M. Kosmin, while exploring this coast, came to a place where a low cliff rose above the beach, the land behind being flat, consisting of clay and earth without a tree or even a bush. The cliff was from twenty to thirty feet high, and was formed of dark earth, partly frozen. Kosmin was journeying in the summer, and the portion of the coast that he was exploring lay between the mouths of the rivers Yana and Kolyma. The earthy rubble of which the cliff was composed was full of vegetable remains

and fragments of trees, and contained many bones of Mammoths, which were scattered through the deposit. At another place the earthy character of the cliff changed into clay.[1] This earthy deposit appeared in many places, and has recently been found along the lower courses of the great Siberian rivers, often at a great height above their beds. Everywhere it is full of the trunks of trees and the bones and tusks of Mammoths and rhinoceroses. It is essentially a fresh-water deposit, and is known as the Mammoth formation. The earthy cliff seen by M. Kosmin is not a glacial deposit, for the beds belonging to the Glacial Period lie *beneath* it. Nor is it forming now, by water discharged from melting snow, because it contains the trunks of trees, and no trees now grow within a hundred miles of the Siberian coast. The presence of the bones of the Mammoth, rhinoceros, and musk-ox in great abundance all through the deposit also proves that it is not forming in the present day, although every winter eight feet of snow covers the lowlands along the Siberian coast, all of which snow is thawed during the brief summer. This earthy deposit is Post-Glacial, and is intercalated between the glacial beds proper and the sand and clays which are forming now. It must have been formed rapidly, because it is full of the trunks of great trees, which must have been torn up by a violent rush of water; while the remains of the great mammalia it con-

[1] Kosmin's account is found in Wrangell's *Siberia and the Polar Sea*, pp. 215, 216.

tains bear witness to the vehemence of the force which swept away these gigantic beasts and tore their bodies asunder, piling their bones on each other in the greatest disorder. This deposit cannot have been formed by rivers, because it often is found hundreds of feet above their beds, and forms cliffs along the shore where there are at present no rivers or streams of any importance.

Here then, we have, I think, a deposit of a similar age and of a similar character to the earth-cliffs at Godrevy, and, like them, formed by powerful aqueous causes during the Quaternary Period. It is true that no organic remains whatever have been found in the Godrevy "Head of Rubble," but perhaps they have been dissolved by the percolation of water through the deposit, or have been destroyed by the powerful marine denudation that has destroyed so much of the formation. A violent aqueous force acting rapidly from the direction of the land formed, in my opinion, the Godrevy Head, but the force is no longer in operation, and quickly expended its energies.

As the Godrevy earth-cliffs are rapidly falling away under atmospheric agencies, and are constantly being worn down by rain, new sections are frequently being exposed. A close watch should be kept on them, therefore, to see if when earthy masses fall on the beach any organic remains or foreign stones or pebbles are laid bare, as it is possible that in this manner further light may be thrown upon their origin.

NOTES ON THE OCCURRENCE OF PSEUDOMORPHS OF OXIDE OF TIN AFTER SOME UNKNOWN MINERAL FROM BOLIVIA.

By Dr. R. Pearce, F.G.S.

On investigating some Bolivian Tin Ores recently, I discovered some interesting crystals, which proved, after examination, to be Oxide of Tin, containing about 70 per cent. of Metallic Tin. I was so much struck with their general appearance and form, that I concluded at once that they were Pseudomorphs after some crystallized mineral.

I submitted a small piece of the mineral containing the crystals to Professor S. L. Penfield, of Yale University, with the hope that he would be able to give me some clue as to their origin, and I have only just received his reply, which is as follows :—

"The crystals certainly look like Pseudomorphs, but of what? The larger ones are so attached that I cannot see enough of any one to determine its form, and are so rough that measurements are out of the question. The problem looks as though it would be a difficult one to work out, perhaps an impossible one. I am quite sure that the crystals are not Pseudomorphs after Feldspar."

It will be seen in the small specimen which I send by post, that the greyish black mineral does not show the usual characteristic properties of ordinary Tin Oxide.

It will also be observed that it is associated with a soft yellow material, which, on examination, is found to consist mainly of Oxides of Lead and Iron, Sulphuric Acid, and a small amount of Arsenic Acid.

I have ventured the opinion that possibly the Tin Pseudomorphs may be the result of alteration, by oxidation, of one of those Sulpho Stannites which are known to occur in Bolivia, and the existence of the yellow mineral, which is evidently a product of oxidation, would almost point to such a change.

I have observed on more than one occasion in examining Bolivian Ores, lumps of Tin Oxide, occurring in forms unlike that of any Tin Ore I have seen from other Tin-producing districts, and it is quite within the bounds of possibility that the cindery-looking cellular masses of Cassiterite may have been formed by the alteration of Sulpho Stannites. Should this prove to be the case, after further investigation of these new Pseudomorphs, and the crystalline form is found to agree with some known form of Sulpho Stannite crystals, we would have pretty conclusive evidence of the secondary enrichment of Tin Ores from the oxidation of Tin Sulphides and the removal of the associated metals.

I shall hope, later on, to present the Society with a more characteristic specimen of this in-

teresting find, as up to the present time Feldspar is the only mineral, except perhaps Specular Iron, which is known to have been replaced by Oxide of Tin.

I shall follow up my investigations with a view of determining the actual composition of the yellow mineral accompanying the Tin Oxide, as shown in the specimen.

Thus far my results, which have been rather crude, would, from the examination of two separate and distinct specimens of the material, indicate some degree of uniformity in composition.

If it can be satisfactorily proved that the Mineral Cassiterite has been formed as a result of the oxidation of Tin-bearing Sulphides, it may possibly aid in solving some of the difficult questions which present themselves in connexion with the Genesis of Tin Deposits.

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OF

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1907.

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ANNIVERSARY ADDRESS OF THE PRESIDENT,

DR. RICHARD PEARCE, F.G.S.

To the General Meeting, October 30th, 1906.

LADIES AND GENTLEMEN,—I shall endeavour in this brief address to follow the line of thought sketched out in my address of last year, in which I referred more especially to that branch of Economic Geology having a direct bearing on the Mining industry of Cornwall. I had hoped to be able to refer to some interesting and instructive developments in this particular branch of Science, as a result of the work of the Geological Survey of Great Britain, but on inquiry I find that nothing has been published during the past year, having a direct bearing on the Cornish mining industry. I have looked, too, for further particulars connected with the interesting discovery of Cassiterite associated with Magnetite in Scotland, but I cannot learn of any fresh developments other than those published in the *Summary of Progress* of the Geological Survey of the United Kingdom for 1903. The wheels of this department of Science move slowly.

During the past year, Cornish Mining would seem to have taken on a new lease of life; pessimistic despair has given place to the brightest expectations for the immediate future welfare of Cornish Mining. This improvement is in a great measure due to the advance in the price of the staple commodity, tin; but I am glad to notice that another very important feature has been

found to play a part in these improved conditions, viz., the discovery that our tin lodes do not, in all cases, indicate barrenness as greater depth is reached. The recent developments at Dolcoath, at a depth of 3000 feet, prove, I think, most conclusively, the persistence of ore deposits at increased depth, and this famous old mine, with over a century's record of continuous work, may be taken as an object lesson, to demonstrate the fact that our old classic veins do not become exhausted at the paltry depth of two or three thousand feet; and that lodes which have been found to be rich in tin at no very great depth from the surface, and have shown evidences of barrenness at deeper points, may still reward the pluck and the enterprise of the miner who has faith in deep mining, and the "wherewithal" to prosecute his search.

I believe I am correct in stating that Dolcoath is the deepest *tin* mine in the world, and yet the depth reached falls short by several hundred feet of the points reached in the mines of Lake Superior, and the gold mines in South Africa and South Australia.

Three thousand feet below the surface can hardly be regarded as a great depth, for it represents little more than the "thickness of a sheet of paper in comparison with a sphere of 2 feet in diameter," and as tin appears to be intimately associated with the older eruptive rocks, we are hardly warranted in coming to the conclusion that tin veins become extinct, or have reached a point where they are no longer productive, at the very moderate depth yet reached by our Cornish mines.

It is, I believe, generally conceded as a result of the careful scientific deductions of the foremost geologists, and the more intelligent mining engineers of the world, that the metallic ores owe their origin to deep-seated sources. Professor J. W. Gregory, F.R.S., in a lecture on "Ore Deposits and their Distribution in Depth," which I was privileged to hear at the Royal Institution of Great Britain, in the spring of this year, and which was published in full in the pages of the *Mining Journal*, referring to deep-seated water circulation as a medium for the distribution of metallic ores, says: "This plutonic water answers all require-

ments for a depositor of ores. It is coming from the proximity of the metalliferous interior of the earth; it is super-heated water, so it is a ready solvent of materials which are insoluble in less heated water; it is usually alkaline, and therefore is the readiest solvent of metallic sulphides, the primary condition of the vast majority of ores. At depths below about 37,000 feet, the temperature would be above the critical point of water, which therefore could not exist as such, its elements would be given forth as separate gases from the slowly cooling 'Magma.' The gases would rise, and having passed into a zone with a temperature below the critical, would combine to form water."

The views held by Professor Gregory on plutonic waters are practically the same as those expressed by Professor J. F. Kemp, of the Columbia University, New York, in his paper, "The *rôle* of Igneous Rocks in the Formation of Veins," to which I briefly referred in my previous address. I have ventured to quote from Professor Gregory's instructive lecture, as it affords additional evidence, from an unquestionable authority, as to the probable origin of mineral deposits, and if the views he expresses so clearly, and which so fully confirm the opinions of other eminent authorities, are correct within reasonable bounds, we have no cause to fear any permanent impoverishment of our Cornish lodes within the limit of what might be termed "mining possibilities."

The mineralogical characters of the tin ore from the deepest point at Dolcoath are best seen in the specimen before you, which I have been able to procure through the kindness of the Manager, Mr. R. A. Thomas. The mass of material is made up of a very dark glassy quartz, containing extremely fine needle-shaped crystals of tourmaline of a pale blue colour—blue peach. The oxide of tin occurs in such a finely divided form that it can scarcely be recognized by the eye, and there seems to be an entire absence of the usual crystalline variety of tin oxide so frequently observed in the deposits in the upper workings of the mine. When present in quantities visible to the eye, the tin oxide is of a grey or greyish white colour, and is especially free

from pyritic minerals, such as ordinary "pyrite," "arsenical pyrite," and "copper pyrite," minerals which were not uncommon associates with tin ore in the upper workings of the mine.

The almost entire disappearance of pyritic minerals in the deeper workings at Dolcoath would almost lead to the conclusion that this may be the general experience, but unfortunately, I have not been able to collect any data in support of this view, owing to the mines that might have furnished the information having either abandoned, or discontinued their deep workings.

I have recently been afforded an opportunity of comparing the relative value of the annual production of black tin, with the crude arsenic obtained by roasting the concentrates, at Dolcoath, from the year 1850 up to 1887, at which latter date, it appears, the sale of arsenic had entirely ceased. I have not been able to obtain the actual weights of black tin and crude arsenic sold during the period named, and as both these products have been subject to great variations in price from year to year, the comparison shows only an approximate ratio. It is sufficient, however, to indicate the gradual disappearance of arsenical minerals as depth is attained. The following condensed table shows the percentage value of arsenic sold, as compared with the sales of black tin :—

1850 to 1859	2·01	per cent.
1860 to 1869	0·94	„
1870 to 1879	0·35	„
1880 to 1887	0.28	„

It has occurred to me that some additional evidence bearing on the association of tin with pyritic minerals, beyond what was furnished in my previous address, might be of some interest, and I have been able, through the kindness of the Manager of Dolcoath, to obtain samples of crude ore from five different points of the deepest workings in that mine ranging from the 440 to the 490 fathoms levels. These samples, numbers 1 to 5 inclusive, represent 275 tons of ore sent to the stamps, and may be taken as a fair average of the ore produced at those points. A careful determination of the sulphur contained in these samples

has been made under my own personal supervision, with the following results :—

Sample No. 1, stopes between 440 and 455 levels, ·24 per cent. sulphur.

Sample No. 2, stopes between 455 and 470 levels, east, trace sulphur.

Sample No. 3, stopes between 455 and 470 levels, west, ·021 per cent. sulphur.

Sample No. 4, 490 east of New Sump, ·053 per cent. sulphur.

Sample No. 5, 490 east and west of Winds, ·026 per cent. sulphur.

A careful examination of the samples that gave marked evidences of sulphur, especially No. 1, showed that the sulphur was evidently combined with iron in the form of ordinary iron pyrites, there being no evidence of arsenical pyrites, so that it may be said that in all the samples there was an entire absence of this latter mineral. If we then assume that the sulphur, as before suggested, is in combination with iron as iron pyrites, the following will represent the percentage of this mineral present, viz. :—

No. 1	·45 per cent.	iron	pyrites.
„ 2	trace	„	„
„ 3	·039	„	„	„
„ 4	·099	„	„	„
„ 5	·048	„	„	„

The mean percentage of these five samples will be ·126 iron pyrites, and if we omit No. 1 from the most shallow of these depths, we have a mean of ·046 per cent. only. These results, I think, substantiate the views on this particular question, that I expressed in my address last year, in which I stated that as the result of a determination of the sulphur in a sample of concentrates from Dolcoath, I calculated the average of the crude ore produced from the mine would contain the insignificant "quantity of ·0178 per cent. of iron pyrites." The above results, I think, prove most conclusively that pyritic minerals are not necessarily accompaniments of tin, so far as indicated in the particular case of the deep workings at Dolcoath.

I have been informed that in certain mines which have arsenical pyrites associated with tin, viz. Carn Brea, Tincroft, East Pool, South Crofty, for example, the ore is mined at a depth not much below 200 fathoms or 250 fathoms from the surface corresponding in depth to its occurrence in Dolcoath.

In considering the question of the probable source of Metallic Ores, it may not be out of place for me to refer briefly to the formation of minerals by what may be termed artificial means, or by combinations effected in the ordinary process of smelting metallic ores.

In the Museum of Natural History, South Kensington, an interesting and instructive collection of certain crystalline minerals may be seen, having all the physical and chemical characteristics of the natural minerals. They are, however, merely furnace products. This collection includes artificially formed cassiterite, augite, diopside, orthoclase, mica, rhodonite, willemite, magnetite, hematite, zincite, wurtzite, and galena, etc. The majority of this series of minerals have been formed by crystallization from a fluid mass of molten material, others again by sublimation, and subsequent condensation on cooled surfaces.

Perhaps the most interesting of this group, and one which more particularly appeals to us Cornishmen, is a beautiful crystalline specimen of cassiterite, said to have been found in the hearth of an Austrian tin furnace. The colour of the crystals is unlike the native variety, being of a dark violet colour. They are large and well defined, as may be seen in the specimen before you, having the same crystalline form as the native mineral, but the propensity to twinning, which is found to exist so abundantly in the native mineral, is curiously absent in the artificial variety. I have endeavoured to obtain some facts which will indicate the conditions under which these crystals have been formed, but without any satisfactory result. It would be interesting to know whether they have crystallized out from some molten material, or were formed by sublimation.

In a somewhat lengthened experience, my attention has been frequently drawn to a number of interesting examples of the arti-

ficial formation of crystalline compounds, as products from the smelting of ores, and it has often occurred to me that their formation may have, in some measure, been effected by causes similar to those which exist deep down in nature's laboratory.

The occurrence of metallic tellurium, as a beautiful crystalline sublimate, the brilliant octahedra of magnetic oxide of iron which has separated out from a highly basic slag on cooling, the formation of definite crystalline alloys of gold and silver, and of gold, silver, and lead, combinations of sulphur with copper and lead and iron, indicate that artificial minerals may be produced in the ordinary operations of smelting, which possess the form and composition of their primitive kin.

By way of example, I may draw your attention to the formation of metallic gold in the hearth of a reverberatory furnace, on which copper ores, containing gold and silver, had been smelted. It will be necessary for me to describe briefly the conditions which exist in the smelting of ores by such methods as are generally adopted. The aim of the smelter is to produce what is called a "matte" or regulus, which shall contain the copper, gold and silver in a more concentrated form than they originally existed in the ore, a concentration in fact of the metals. Normal "matte" may be said to consist of copper and sulphur with varying quantities of iron, together with certain impurities such as lead, arsenic, antimony, bismuth, etc., the latter elements being generally present in company with gold and silver.

If we study what happens when a mass of molten material in the form of "matte" is almost in constant contact with the upper surface of the hearth of the furnace, we find that absorption of molten "matte" by the hearth takes place, rapidly at first, when the hearth is new, and slowly increases, until a condition approaching saturation is reached. We find too that a separation takes place of certain easily fusible compounds of sulphur with copper and lead, so that a series of definite compounds are produced, having varying degrees of fusibility and specific gravity, and differing in chemical composition and physical characters.

The most easily fusible of these compounds find their way down below the smelting zone, and into the cooler parts of the hearth, where they crystallize out and form, frequently, an interesting series of products, not unlike, in some cases, certain minerals which occur in nature. Crystalline alloys of gold and silver, and gold, silver, and lead, have been met with in the joints of the brickwork which forms the support of the hearth. In the case of the crystalline alloy of gold and silver, which has a high melting point, and therefore could not have reached the cool parts of the hearth in that form, there is abundant evidence to show that the metals were originally associated with lead, which caused their low fusibility, and that a secondary action had taken place, by which the lead became oxidized into minium or red lead, the alloy of gold and silver crystallizing out in all its purity, with a brilliancy of lustre, and a perfection of crystalline form, equal to the metals and alloys found in nature.

The formation of metallic gold as shown in the specimen before you is the result of the action of water on a furnace hearth, which was impregnated in the manner I have described, by copper matte containing gold, in combination with sulphur. In the particular case to which I refer, a furnace hearth having a surface area of about 250 square feet, and a total thickness of nearly two feet, representing a mass of red-hot material of about 45 tons in weight, was cooled, by allowing a stream of cold water to flow on its surface, until the whole mass was sufficiently cool to allow of its being broken up and removed. The solvent action of the water even at the ordinary pressure of the atmosphere was remarkable. Sulphates of copper and iron were formed in large quantities by the oxidation of the absorbed copper matte, and at a spot near the centre, and some few inches below the surface, a loose friable mass of material was found, containing fresh bright deposits of metallic gold. Previous to the addition of water to the hearth, the gold must have existed diffused through the matte, and, as in the case of the other metals present, combined with sulphur. In other words, the gold could not, under the circumstances, have existed in a free state.

The only explanation one can offer is, that the water must have dissolved the gold through the aid of certain metallic salts it held in solution, and that the gold was subsequently precipitated in a spongy form, in contact with reducing substances, when the conditions favoured precipitation.

It is quite within the bounds of possibility to suppose that changes analogous to those I have referred to, occur in the natural deposition and diffusion of metals and their ores at great depths. The minerals and metals which are to be seen within the extremely narrow limits of the space at present accessible, are undoubtedly of secondary origin, having been brought upwards through the agency of water from their deep-seated source, where the conditions which exist may be not unlike those which I have referred to in the case of the furnace hearth, only in a more intensified form, as a result of high temperature and pressure. The furnace hearth may be compared in a microscopic degree to the highly heated zone, which is supposed to exist above the fluid "magma," and which absorbs the emanations from the fluid mass below; these emanations would condense and occupy varying positions, depending on their degree of volatility, fusibility and specific gravity, and would be diffused through an enormous mass of highly heated material.

The action of water on such a material, whether of Plutonic or Meteoric origin, would naturally be that of a powerful solvent for the metals and their compounds. The solutions in their progress upwards would undergo a series of changes, such changes being governed or influenced by the composition of the mineral solutions, and the physical and chemical characters of the rocks through which they would travel to the earth's surface.

Such a comparison as I have attempted to draw may appear to be somewhat presumptuous; they are merely suggestions, however, which I believe are not at variance with the generally accepted theory as to the origin of metals, accentuated, perhaps, in my own mind by observations extending over many years' experience in the smelting of ores.

Any theory which may be advanced as to the origin of our mineral wealth should be of some value, provided it is based on observations and facts which are not at variance with the teachings of science. The exact laws which govern mineral deposition will never be known with certainty, for they are in operation beyond the reach of human intelligence. By the aid of the spectroscope chemists can pronounce with certainty on the existence of metals in the sun's atmosphere, millions of miles from the observer, and the metals can be named with as much accuracy as if they were present in one of our museums, or in the chemist's laboratory; but the interior of the earth will, perhaps for all time, remain a sealed book, and we must be satisfied to base our theories and conclusions on such evidence as comes under our observation, and appeals to our reasoning powers.

There are records of the recent existence of hot springs in some few of our mines, such as Wheal Clifford, Wheal Seton, and Dolcoath, the most remarkable being that of Wheal Clifford, which has no doubt been referred to in the Transactions of this Society. It may perhaps not be considered out of place for me to refer to it again by way of illustration.

I find on looking up the old numbers of the *Chemical News*, that in 1864 the water from this spring was analysed by Professor Miller, F.R.S., then Professor of Chemistry at King's College, London. The sample of water was collected under the direction of the late Mr. Horton Davy, of Bochym, and the temperature determined by the late Sir Warrington Smyth. The spring was found to issue from the copper vein at a depth of 230 fathoms, or 220 fathoms below the mean level of the sea. The flow of water was estimated by Mr. Davy to be 150 gallons per minute, and the temperature according to Sir Warrington Smyth was from 122° to 125° Fahr., the temperature of the air being at that point 110° Fahr. Professor Miller's analysis, which appears to have been very exhaustive, showed that the water contained 646·1 grains of solid matter per gallon. The analysis of this solid matter demonstrated the curious fact that about 1-25th part of the entire contents per gallon consisted of chloride of lithium, or to be more

accurate 26·05 grains per gallon. The following is the complete analysis as furnished by Professor Miller:—

Chloride of Lithium	26·05
Chloride of Potassium	14·84
Chloride of Sodium	363·61
Chloride of Magnestum	8 86
Chloride of Calcium	216·17
Sulphate of Lime	12·27
Silica	3·65
Total grains per gallon	645·45

A simple calculation shows that in a period of one year, provided the flow of water and the soluble contents were uniform, no less than 3248 tons of solid matter would be brought to the surface, mixed with the natural drainage water of the mine, and 130 tons of this quantity would consist of that very precious salt, chloride of lithium.

I can personally bear testimony to the high temperature and volume of this spring, for in March of the same year (1864) I was engaged by the Royal Commission of Mines, known at that time as "Lord Kinnaird's Commission," to collect samples of air from the lower workings of the mine for analysis by the late Dr. Angus Smith and Dr. Albert Bernays. These samples had to be collected in glass tubes, which were sealed by the help of a mouth blowpipe, and I can well remember the difficulties I experienced in my work from the extraordinary conditions of temperature and moisture.

Wheal Clifford Mine was abandoned soon after the discovery of the Lithia spring, and the workings are now filled with water. In all probability, however, the spring is still active, but the opportunity of reaping substantial benefit from it as a commercial source of Lithium, has been lost.

From a purely scientific point of view, I think it is most fortunate that we possess the records of this investigation, as they serve to illustrate the magnitude of the changes which exist at a considerable depth below the surface, as the result of highly heated water circulation, through veins and fissures, and

as an example of the methods adopted by Nature in transferring the metallic treasures from great depths below, to points within the reach of man's intelligence and skill. I must not forget to mention that this interesting subject of deep water circulation in its relation to Cornwall has been treated in a most exhaustive manner by my predecessor in office, Mr. J. H. Collins, F.G.S., in his work on "The Origin and Development of Ore Deposits in the West of England."

By way of conclusion I am tempted to quote three brief paragraphs which I have copied from a course of lectures on "The Old and New Chemistry," delivered in the spring of this year, at the Royal Institution of Great Britain, London, by Professor Sir James Dewar, F.R.S., etc. In his lecture he traces the gradual development of chemical knowledge from a very remote period down to the present day, and he gives quotations from a number of authors bearing on the subject.

The selections I have made are from the writings of Pliny, Liebig, and Sir Humphry Davy, as I judge they may be considered to have some bearing on the subjects I have ventured to discuss in this address.

First there are Pliny's views of some marvellous facts connected with fire :—

"Having now described all the creations of human ingenuity, reproductions, in fact, of nature, by the agency of Art, it cannot but recur to us with a feeling of admiration, that there is hardly any process which is not perfected through the intervention of fire. Submit to its action some sandy soil, and in one place it will yield glass, in another silver, in another minium, and in others again, lead and its several varieties, pigments and numerous medicaments. It is through the agency of fire that stones are melted into copper; by fire that iron is produced and subdued to our purpose, by fire that gold is purified, by fire too that the stone is calcined which is to hold together the walls of our houses. Some materials again are all the better for being repeatedly submitted to the action of fire; and the same substance will yield one product at the first fusion, another at the second, and another at the third. Charcoal when it has passed

through fire, and has been quenched, only begins to assume its active properties; and when it might be supposed to have been reduced to annihilation, it is then that it has its greatest energies.

"An element this of immense, of boundless power, and as to which it is a matter of doubt whether it does not create even more than it destroys."

Second: Liebig on the "Elements of the Alchemi and Alchemy."

"In order to attain that knowledge of chemistry which we now possess, it was necessary that thousands of men, armed with all the science of their respective periods, and inspired with an unconquerable ardour, with a passion for knowledge, which in its violence bordered on madness, should devote life, fortune, and their whole faculties, to the task of exploring the earth in all directions.

"It was necessary that with indefatigable perseverance and constancy, these men should bring into contact all known substances, organic and inorganic; it was necessary that these labours should be continued for fifteen centuries.

"There was finally a mighty, an irresistible charm, which urged men to devote themselves with an amount of patience and perseverance altogether unexampled in history to labours which did not tend to supply any want peculiar to the time in which they lived. This mighty impulse was nothing else than the desire for earthly happiness.

"By a wonderful and wise dispensation there was implanted in the minds of the wisest and most experienced men the idea of the existing of a thing hid in the bowels of the earth, by the discovery of which man might become possessed of those things which imply the gratification of the utmost desires of a refined sensuality—namely, gold, health, and long life. Gold gives power; without health there is no enjoyment, and longevity here takes the place of immortality."

Third: Sir Humphry Davy on "Works of Alchemical Adepts."

"Nothing can be stronger or more just than what Lemery said of these men, that they professed an art without principle, the beginning of which was deceit, the progress of which was falsehood, and the end beggary. There were however enlightened alchemists, men who modestly asserted that their means were in-

adequate to produce effects, which they conceived to take place in the external world, who, considering the metals as generated beneath the surface of the earth by unknown operations, directed their views towards the discovery of these processes, and had for their highest object the construction of a laboratory in art, corresponding to the great laboratory of Nature."

REPORT OF THE COUNCIL

To the Annual General Meeting, October 30th, 1906.

THE Society has now completed the ninety-third year of its existence, and the Council believe they can honestly place on record that during the past twelve months the work of the Society has been satisfactorily continued, and that the building and collections are in good order.

Several specimens have been added to the collection, as is shown in the Curator's report, and the additions to the Library are even larger than usual, for all of which the Council record their thanks to the several donors.

The Council are pleased to learn that the new Geological survey is making satisfactory progress, the description of the Isles of Scilly, with accompanying map, being completed, and the receipt of copies for the Library is gratefully acknowledged.

Mr. Clement Reid, F.R.S., has expressed a hope that the Memoir relating to the Land's End and Penzance will soon be in print. He writes: "A great deal remains to be done in working out the relation of the ore-deposits to the geological structure; but time after time I find that the mines have been closed, and that the information that ought to have been preserved has been hopelessly lost. I am daily coming across problems that may be better solved in Cornwall than elsewhere."

This loss of information is a matter to which this Society called attention some years ago, and now that so many of the abandoned mines are being examined and reopened, it is being seriously felt. It is to be hoped that in the future more care may be exercised in its preservation, as it, with the new survey,

will be of undoubted value in the development of the mining industry.

The Council have had under consideration Mr. H. Fox's letter to the President of the 29th October, in which he expresses his opinion "that the future usefulness, influence and credit of our Society will be much increased by our getting into closer connection with the mining interests of the county. The present revival of mining enterprise makes this a peculiarly suitable time for attempting a new departure. The yearly awarding of the Bolitho Medal should be an incentive to those acquainted with mining operations to send us valuable papers which could be discussed at our annual meetings, which might be held in turn at Camborne, Redruth, and Penzance."

The Council are completely in sympathy with Mr. Fox and have the matter referred to under their consideration; and hope to be able to take some practical steps in the direction indicated at an early date.

The Council have decided to award the William Bolitho Medal for this year to Andrew Ketchan Barnett, F.G.S., of Penzance; an award which is not only justified by Mr. Barnett's high reputation as a mineralogist, but which they hope will serve as some recognition of the excellent work which he has done in scientific education during more than thirty years. In the Annual Report of this Society in 1874, reference is made "with pleasure to the result of the instruction on Mineralogy given by Mr. Barnett in the Society's class-rooms."

The classes were continued on these premises, and under the auspices of the Society, for many years, and out of them, through the energy and perseverance of Mr. Barnett, has directly grown the existing Penzance Mining School. The Council know they are expressing the unanimous feeling of the members in hoping that Mr. Barnett may be able to continue his good work for many years to come.

The Council regret to record during the year the deaths of M. Vivant-Léon Moissenet, the distinguished French mineralogist,

who was for more than forty years an honorary member of the Society; of the Lord Bishop of Truro, and Mr. F. G. Enys.

The Council recommend the election of Mr. A. K. Barnett as President for the next two years; and the re-election of the other officers of the Council, substituting Dr. R. Pearce in the place of Mr. A. K. Barnett on the Council.

The President presented the William Bolitho Medal to Mr. A. K. Barnett, with the following words:—

It affords me much pleasure as President of this Society to carry out the unanimous wish of the Council in presenting you with the William Bolitho Medal.

My long absence from Cornwall has prevented me from being an actual witness of your scientific work in the County, but judging from what I have had an opportunity of learning from my friends, and from those who are more particularly capable of forming an opinion as to the merits of your work, there can be no doubt but that you are a worthy recipient of the honour.

I find that as early as 1873 you were an active worker in connection with the Miners' Associations of Cornwall and Devon, and the scientific knowledge which you at that time acquired prompted you to an investigation of those interesting rocks known as Cornish Elvans. These studies took the form of a Prize paper entitled "Observations on the Elvan Courses, Greenstones, and Sandstones of Cornwall."

In this investigation you had the good fortune to point out, as an original discovery, some miles of Elvan courses which had been unnoticed and unmapped by previous investigators.

You were also the first to draw attention to the interesting series of Mica traps.

For these researches you were awarded the first-class Silver Medal of the Royal Cornwall Polytechnic Society, and for a duplicate collection of rocks you gained the first of the prizes offered by Mr. J. A. Phillips, F.G.S., on the award of the late Sir Warington Smyth, F.R.S., and Robt. Hunt, F.R.S.

Your scientific acquirements have done you good service in connection with your subsequent appointments, in Spain, at the Rio Tinto Mines, and in Cornwall as chief of the Chyandour Tin Smelting Works, and later on, as the founder and principal of the Penzance Science and Mining School.

The Penzance district has honoured you in selecting you to serve as a member of the County Council, where your scientific attainments qualify you for great usefulness in the Educational deliberations of that body.

You have also rendered valuable aid in the arrangement of this Society's collection of rocks and minerals for purpose of study. It only remains for me to hand you this beautiful Medal in the name of the Society, and to express a wish that it may act as an additional incentive to further useful work in the cause of Science, and especially in that branch of scientific work which bears more particularly on the geology of Cornwall.

In returning thanks Mr. Barnett said:—

First allow me to thank you very heartily for the flattering expressions you have used towards me in making this award. I assure you I prize highly the very distinguished compliment the President and the Council of this learned Society have paid me in selecting me as the recipient of the Society's Award of Merit. I am proud to receive this Medal for several reasons: first, the founder whose image and name it bears, William Bolitho, a name which I have reason to cherish with the highest respect, was a very kind friend and patron to me during the years that he was associated with this Society as its Treasurer. He was always ready with his influence and practical sympathy to help and assist in that work which I made my own—the formation of classes for the teaching of those science subjects which are so closely identified with the aims of this Society and which were first established in the basement of the Society's Museum, and from which the present Mining and Science School of this town has developed. I am also proud to receive this Medal from the President, as I recognize in him not only the President of the

Royal Geological Society, but I also see one of the early teachers of that Society, "The Miners' Association of Cornwall and Devon," which did such noble work in past years for the scientific and technical education of the miners and young men of Cornwall. Many in this county are deeply grateful to Dr. Pearce, the late Mr. Twite, the late Sir Clement Le Neve Foster, our friend Mr. J. H. Collins, and others, for the instruction given in the classes of that Society, which enabled them to take positions in the mining and metallurgical world which otherwise they could not occupy. I had the good fortune in my early days to receive instruction from the late Sir Clement Le Neve Foster and Mr. J. H. Collins, and it is to the love of science inoculated by them that I owe my position here to-day. I again thank the President and the Council of this Society for the very high honour they have bestowed on me in awarding me the William Bolitho Gold Medal. I remember and treasure the friendships I have made among the members of the Society, the kindly co-operation and assistance the members always give to my work, the practical value of the rich collections of minerals and fossils to myself and students in the past, and last, but surely not the least, the kindly feelings which prompted the judge to award me this Medal and to associate my name with the names of the illustrious members of this Society to whom it has been awarded in the past. I only feel that I wish I was more deserving of this special mark of your appreciation.

LIBRARIAN'S REPORT.

1906.

THE Librarian acknowledges, with thanks, the receipt of publications from the following :—

American Philosophical Society.
—— Academy of Arts and Sciences.
—— Academy of Natural Sciences.
—— Geographical Society.
Augustana College.
Batavia. Jaarbock.
Belfast Naturalists' Field Club.
Belgium. Société Belge de Geologique.
Bristol Naturalists' Society.
British Association.
Buenos Aires. Museo Nacional.
Canada. Geological Survey.
——. Royal Society.
Canadian Institute.
Cincinnati Society of Natural History.
Colorado Scientific Society.
—— College Studies.
Cornwall, Royal Institution.
—— Royal Polytechnic Society.
Dorpat. Naturforscher Gesellschaft bei der Universitat Jurjew.
Dublin Royal Society.
Edinburgh Royal Society.
Edinburgh Geological Society.
Eastbourne Natural History Society.
Elisha Mitchell Scientific Society.

Geological Survey.
Geological Society.
Geologists' Association.
India. Geological Survey.
Indiana. Academy of Science.
Iowa. Geological Survey.
Kansas Academy of Science.
Leicester Literary and Philosophical Society.
Liverpool Literary and Philosophical Society.
—— Geological Society.
London and West Country Chamber of Mines.
Manchester Geological Society.
—— Geographical Society.
—— Microscopical Society.
Marine Biological Association.
Maryland Geological Survey.
Mexico. Instituto Geológico.
Missouri. Geological Survey.
Monte Video. Museo Nacional.
New York Academy of Sciences.
New Zealand. Department of Mines.
New South Wales. Geological Survey.
Normandy. Société Geologique.
North of England Institute of Mechanical and Mining Engineers.
Nova Scotia. Institute of Sciences.
Peru. Cuerpo des Ingeniores de Minas.
Philadelphia. Academy of Natural Sciences.
Plymouth Institution.
Queensland Government.
Rochester (U.S.A.) Academy of Sciences.
Royal Society.
Saxony. Berg und Huttenwesen.
Smithsonian Institution.
South Australian School of Mines.
Tuscany. Societa di Scienzi Naturali.
United States. Geological Survey.
Vienna. K. K. Geologischen Reichsanstalt.

Vienna. K. K. Naturhistorichsen Hofmuseums.
Victoria. Geological Survey.
Western Australia. Geological Survey.
Yorkshire Geological Society.

[*From the Authors.*]

The Iron Ore Deposits in Sydvaranger. By G. Henriksen, Christiania.
Sundry Geological Problems. By G. Henriksen, Christiania.
The Physical Geography of Essex County, Mass., U.S.A. By J. H. Sears.

[*Purchased.*]

Palæontographical Society. Vol. lviii.
London, Edinburgh, and Dublin Philosophical Magazine.

CURATOR'S REPORT.

DONATIONS TO THE MUSEUM.

THE Curator acknowledges with thanks the receipt of the following additions to the Society's Museum.

By HALLET G. BATTEN :—

Tin, from reef, Mergui District, Tenasserim, Burma.
Tin, from Maliwun, Burma.
Gold Quartz, from Perth, Australia.
Crystal, from Tavoy, Burma.

By W. NICHOLAS, F.G.S. :—

Mica, from Central Australia.

By R. PEARCE, F.G.S. :—

Native Gold, from Ontario Mine, Colorado.
Tin Oxide, with Pyritous Minerals, from Straits Settlements.
Quartzite containing Cassiterite, from Monte Blanco Mine, Tres Cruces, Bolivia.
Section of same.

By DR. R. PEARCE :—

Gold Crystal, artificially produced in a furnace hearth.

By R. A. THOMAS :—

Specimens of Tin, from 490-fathom level, Dolcoath.

By TRUSTEES OF BRITISH MUSEUM :—

Electrotype reproduction of *Sympterura Minveri.*

In connection with this last the following letter is printed for the sake of record :—

GEOLOGICAL DEPARTMENT,
BRITISH MUSEUM (Natural History),
CROMWELL ROAD,
LONDON, S.W.
27 *October*, 1906.

To the Hon^y. Secretary
of the Royal Geological Society of Cornwall.

DEAR SIR,

I have pleasure in sending herewith, on behalf of the Trustees of the British Museum, an electrotype reproduction of the holotype and only known specimen of *Sympterura Minveri*, as a donation to the Museum of your Society. The original specimen, found by Miss Barbara Legg in the Devonian slate of Epphaven in the parish of St. Minver, Cornwall, was presented to the Trustees by Mr. Howard Fox, and a description of it has been published in the *Geological Magazine* (April, 1905, pp. 161–169, pl. vi.), and in your own *Transactions* (June, 1905, vol. XIII, pp. 71–85, pl. ii.).

I am, dear Sir,
Yours faithfully,
F. A. BATHER.

By T. C. HALL :—

Photograph of Tinstone, from 250-fathom level, Dolcoath Mine.

Photograph of portion of Tin Lode, from 152-fathom level, Great Wheal Vor Mine, Breage.

THE WILLIAM BOLITHO MEDAL,

which is provided for by a fund bequeathed to the Society for the purpose by William Bolitho, of Ponsandane, in 1895, has been awarded to the following members :—

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1906. A. K. Barnett, F.G.S.

STATEMENT OF RECEIPTS AND EXPENDITURE FOR THE YEAR 1906.

Dr. *The Treasurer in Account with the Royal Geological Society of Cornwall.* **Cr.**

Receipts.

October 31st, 1906—	£	s.	d.	£	s.	d.
To Ordinary Subscriptions . . .	43	1	0			
,, Subscription per His Royal Highness the Prince of Wales . . .	20	0	0			
,, One Year's Dividend on £1800 Midland Railway 2½ % Debenture Stock, £45, tax £2 5s. . .	42	15	0			
,, Sales of *Transactions* . . .	4	1	0			
				109	17	0
				£109	17	0
October 30th, 1906—						
To Balance in Treasurer's hands				13	16	8

Expenditure.

October 30th, 1906—	£	s.	d.	£	s.	d.
By Balance				10	11	5
,, Rates and Taxes	0	8	0			
,, Curator's Salary	42	15	0			
,, *Transactions*, Periodicals, Printing, etc.	18	19	6			
,, Fire Insurance Premium . .	2	12	9			
,, Coals and Gas	9	13	5			
,, Sundry Repairs	4	5	0			
,, Palæontographical Society . .	1	1	0			
,, Postages, Carriage of Parcels . .	5	14	3			
				85	8	11
,, Balance				13	16	8
				£109	17	0

PENZANCE, *October 30th*, 1906.

T. R. BOLITHO, *Treasurer.*

W. BOLITHO GOLD MEDAL ACCOUNT.

Dr.	£	s.	d.	Cr.	£	s.	d.
March 27th, 1906—				October 31st, 1905—			
To Gerrard and Co.	12	10	0	By Balance	528	15	8
October 30th, 1906—				October 30th, 1906—			
Balance	529	9	1	By One Year's Interest	13	3	5
	£541	19	1		£541	19	1
November 7th, 1906—				October 30th, 1906—			
To Gerrard and Co.	12	10	0	By Balance	529	9	1
Balance	516	19	1				
	£529	9	1		£529	9	1
				November 7th, 1906—			
				Balance	516	19	1

LIST OF PAPERS

READ TO AND PUBLISHED BY THE SOCIETY.

1906.

President's Address. By Dr. R. Pearce, F.G.S.

The Discovery in West Cornwall of a Silurian Crinoid characteristic of Bohemia. By F. A. Bather, M A., D.SC.

On a Microscopic Section of Quartzite containing Tin, from Bolivia. By D. A. MacAlister.

THE DISCOVERY IN WEST CORNWALL OF A SILURIAN CRINOID CHARACTERISTIC OF BOHEMIA.

By F. A. Bather, M.A., D.Sc., Hon. Member R.G.S. Cornwall.

(Read 26 October, 1906.)

In April, 1906, Mr. Clement Reid asked me to examine some obscure fragments, apparently crinoidal, obtained by himself and by Mr. W. G. Fearnsides from Catasuent Cove, Porthluney, Cornwall. The formation that yielded these fossils is the same as "the Black slates with limestone lenticles or inclusions," which occur near Porthalla and at Porthluney, near Gorran. Mr. Upfield Green (*Geological Magazine*, July, 1904, p. 289) has already announced the discovery of Ludlovian fossils in one of these limestone inclusions at Porthluney, while he and Mr. C. D. Sherborn (*Geological Magazine*, January, 1906, p. 33) have recorded the occurrence of other Ludlovian fossils at Porthalla and of a limestone lenticle with Upper Wenlockian fossils at Porthluney. It was a similar limestone

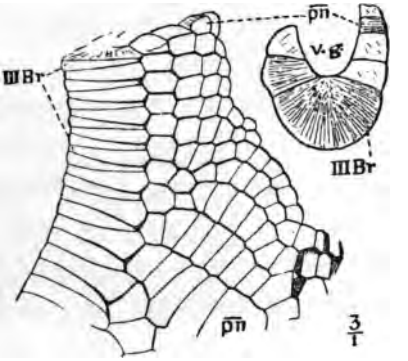
lenticle that yielded the echinoderm fragments which I have had the pleasure of studying.

While the present does not appear a fitting occasion for submitting a detailed technical account of these fragments, with all the evidence and illustrations needed to prove my conclusions, still those conclusions are, from three distinct points of view, of such interest that it seems right to lay them before the Royal Geological Society of Cornwall without further delay.

Most of the fragments are in the form of tessellated pavements, and some, if not all, of these are the remains of those curious, somewhat lobate, spheroidal bodies called "loboliths" by Barrande, and, owing to their possession of internal septa, described as *Camarocrinus* by James Hall. The opinion of Hall that each of these spheroids was attached to the distal end of some crinoid stem, and represented a kind of swollen root, is now generally accepted; and it is further believed by many that this swelling was hollow and served as a float from which the crinoid hung, arms downwards. The latter hypothesis explains why it is that in various parts of the world the loboliths occur unassociated with the crowns to which they are supposed to have belonged; for on the death and gradual decay of the animal the crown would naturally drop off and sink to the bottom, while the lobolith floated on. The question thus arose, To what crowns did the loboliths belong? So far as Europe is concerned, the answer, first suggested by Dr. O. Jaekel,

appears to be that the crowns belonged to the genus *Scyphocrinus*. Definite proof of the correctness of this answer is, by the very nature of the problem, difficult to obtain. The main arguments were that, in Bohemia, various species of this genus abounded in rocks of the same age as those containing the loboliths, and that they were of a size and possessed a stem that agreed well with the hypothesis. More recently Dr. J. J. Jahn and Professor C. Schuchert have announced an almost indisputable connection between a *Scyphocrinus* and a lobolith. (See Schuchert, *Smithsonian Miscellaneous Collections*, XLVII, pp. 259, 262, November, 1904.) It is therefore of much interest to find that this small lenticle of limestone at Catasuent Cove has furnished not only fragments of loboliths, but also fragments of stems and arms which are certainly to be referred to *Scyphocrinus*. The association is such that it would be unreasonable to doubt the derivation of all the fragments from the same animals. Though the stem of the European *Scyphocrinus* has often been found, its joint-faces were not described or figured until Schuchert (op. cit., p. 262) published a single illustration. These Cornish specimens present numerous joint-faces, which, from their resemblance to the similar joint-faces found on some loboliths, furnish additional proof of the former connection between the loboliths and *Scyphocrinus*. They also show variations approaching the structure supposed by Schuchert to be characteristic of the American

Camarocrinus alone. Some of the arm-fragments show the peculiar and characteristic structures represented in the annexed figure, namely the alternation of the brachials (*III Br*) and the union of the fixed pinnulars ($\overline{pn}$) into a pavement which increases the depth of the ventral groove (*v.g.*).



Scyphocrinus excavatus, var. *Schlotheimi*. Part of the arms, from British Museum specimen 15,417, from Bohemia. Enlarged 3 diameters. (From *Ann. Mag. Nat. Hist.*, July, 1900, p. 117.)

So much for the anatomical and systematic interest of these fragments. Let us now consider them from the point of view of geographical distribution. It is for the present unnecessary to allude further to the American loboliths, which may, or more probably may not, belong to precisely the same genus. So far as Europe is concerned, *Scyphocrinus*, with its loboliths, is abundant in Bohemia, while it has been recorded from Poland, the Kellerwald in Prussia, and the French Pyrenees; but it has never been found in the Anglo-Scandinavian basin, which has yielded such

an enormous number of other Silurian crinoids. Its occurrence at Catasuent might be explained in three different ways: (1) by assuming that *Scyphocrinus* had a wider distribution than it has hitherto been credited with, and was a normal inhabitant of the Anglo-Scandinavian basin, in spite of the fact that assiduous search for over a century found no trace of this large and peculiar fossil; (2) by the hypothesis that this part of Cornwall was not covered by the Anglo-Scandinavian Silurian Sea, but fell within the Central European province; that these individuals were isolated stragglers from that province is not very likely, for, if they were, one would scarcely expect to find arms, stems, and loboliths still in association; (3) on the supposition that the various limestone inclusions in the black slates are not of local origin, but that some of them at least have been brought from further south or south-east by agencies which I leave to the imagination of others to suggest. Which of these explanations is correct may perhaps be decided when much more evidence has accumulated. Meanwhile we pass to the consideration of the fossils as evidence of age.

In America loboliths have been obtained from Maryland, Tennessee, and Indian Territory, in all which localities they are restricted to rocks of approximately Helderbergian age, some believed to be at the very summit of the Silurian, others at the base of the Devonian. *Scyphocrinus* has not been found on that side of the Atlantic, and it is there-

fore doubtful whether the American loboliths belong to that genus.

In Europe the rock in which *Scyphocrinus* has been found in profusion is a limestone occurring in reef-like bands between the beds *e* 1 and *e* 2 of the Bohemian Silurian system, and approximately the equivalent of our Woolhope Limestone. One species has also been found in *e* 2; but not one specimen is known from stage *F*. The specimens from Catasuent Cove being undoubtedly *Scyphocrinus*, the natural inference is that the block of limestone from which they came was of Lower Wenlockian age.

Thus there appear to be represented in these "Slates with inclusions" limestone masses of three different ages: Lower Wenlockian, Upper Wenlockian, and Ludlovian. There is even a suspicion, I gather from Mr. Reid, that Ordovician fragments are also present. Without visiting the locality no one should attempt to form any opinion as to the origin of this complex. It should, however, be noted that, fragmentary and obscure though the present fossils are, they show no signs of crushing or shearing.

The occurrence of inclusions of different ages indicates, of course, that the containing rock was formed at a period subsequent to the consolidation of the latest of these. It cannot, therefore, well be older than Devonian. For a general discussion of the relations of this and the associated rocks I need only refer to the recent paper by Mr. J. B. Hill, R.N.

(*Geological Magazine*, May, 1906, p. 206), a paper which at least shows how extraordinarily complicated the problem must be. I hope that the present note may have contributed one tiny fact towards its ultimate solution.

NOTE added 6 Feb., 1907.—The latest remarks on the stratigraphical relations of the rocks in question are to be found in the *Summary of Progress* of the Geological Survey of the United Kingdom for 1905, pp. 24–26, December, 1906. F. A. B.

ON A MICROSCOPIC SECTION OF QUARTZITE CONTAINING TIN, FROM BOLIVIA.

By D. A. MacAlister.

The main mass of the specimen consists of rounded quartz grains, the interstitial spaces being filled with quartz grown in optic continuity. The quartz

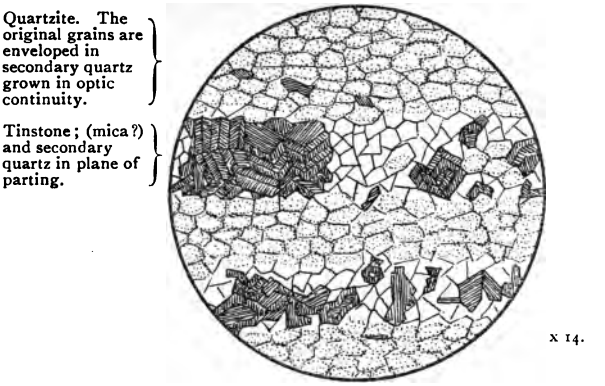


Diagram of Micro-slide showing Tinstone in Bolivian Quartzite.

shows no strain shadows. In the hand specimen the cassiterite is clearly seen to occur along thin, dark bands running parallel with the bedding of the rock. Under the microscope the cassiterite occurs

as irregular crystals (with usual zonary banding) embedded in a mosaic of quartz grains largely or entirely of secondary growth. Some of the cassiterite grains are broken, but there is no real brecciation. No other minerals occur with the doubtful exception of white mica. A little cassiterite is also seen in the part of the rock near the bands.

The rock is a quartzite derived from sandstone. The dark bands appear to be actual veins formed along bedding planes, and are composed of quartz and tinstone—the quartz being a secondary growth on that of the country rock. This interesting specimen was obtained by Mr. Richard Pearce, who presented it to me.

R 89
G 34T

Vol. XIII. Part IV.

TRANSACTIONS

OF THE

Royal Geological Society

OF

CORNWALL,

INSTITUTED FEBRUARY 11th, 1814.

The Ninety-fourth Annual Report of the Council,

WITH THE

REPORTS OF THE TREASURER, LIBRARIAN, AND CURATOR,

AND PAPERS READ TO THE SOCIETY.

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THE NINETY-FOURTH

ANNUAL REPORT

ETC.

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1908.

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THE

ANNIVERSARY ADDRESS OF THE PRESIDENT,

A. K. BARNETT, ESQ., F.G.S.

To the General Meeting, October 29th, 1907.

THE year 1907 is important in the history of Geological Science and investigation, as this year the Geological Society of London has been commemorating the hundredth anniversary of its existence. On the 13th November, 1807, a few notable men, including that celebrated Penzance man, Humphry Davy, met at the Freemasons' Tavern in London, and instituted a Geological Society which developed into the present Geological Society of London, the history and progress of which, with the labours and writings of the many distinguished men whose names have since appeared on its list of members, and whose splendid services rendered to the study of the science have won for that—the premier Society—the respect and esteem of geologists in all countries. It was therefore only fitting that geologists, representing societies from all parts of the world, should have met in London a few weeks since, to acclaim the Geological Society of London—so rich in accomplishment and traditions—as the mother of all their societies, and acknowledge the great influence it has had upon the development of Geological research, and the building up of the subject as a recognised department of science.

Minerals and fossils had attracted the attention of the earliest writers, and speculations on gems, stones, minerals, and fossils are recorded by the old philosophers of Greece and Rome, yet

geology as a science, as we understand it to-day, and which Lyell defined as, "The science which investigates the successive changes that have taken place in the organic and inorganic kingdoms of nature; and inquires into the causes of those changes, and the influence which they have exerted in modifying the surface and external structure of our planet," is one of the youngest of the sciences, whose name only exists from 1778, when it was introduced by J. A. De Luc, and who some years later observed: "Of all the sciences, the most extensive and the most complex is that which was termed Geology, before it was entitled to the name." Though the modern student may find it difficult to realise that the serious study of the subject, raising it to a distinct and recognised science, began little more than a century ago, yet the word Geology was omitted altogether from the *Encyclopædia Britannica* published in the year 1800. For many centuries previously the subject of the history of our globe had engaged the attention of the cosmogonists, who indulged in the most extravagant speculations and theories on the origin and history of the earth, yet amidst the wild speculations of many of these early writers there is often to be found a record of facts pointing to careful and patient observations.

Though topographically far removed from London, Cornwall was one of the first intellectual centres in Europe to follow the lead of the Metropolis in establishing a society for the study and promotion of Geological Science, and on the 11th February, 1814, or a little over six years after the formation of the Geological Society in London, the Royal Geological Society of Cornwall was instituted, and included amongst its honorary members two of the founders of the Geological Society of London—one, its first President, George Bellas Greenough, the other Sir Humphry Davy, and in 1818, three years after the publication of William Smith's *Geological Map of England*, the Royal Geological Society of Cornwall published the first volume of its transactions. As Smith's *Geological Map* is regarded by many as laying the foundation of the present Science of Geology, the history of the Society over which I have the privilege of pre-

siding to-day is contemporaneous with the history of the Science itself. With few exceptions the writers on the minerals, rocks, and general physiography of Cornwall previous to the foundation of this Society possess an historical rather than a scientific interest to the student. If he is liberal minded he is prepared to admire "the earnest toil and endeavours," but he recognises at the same time the grievous but necessary limitations of their knowledge in other directions, and the many difficulties by which most seekers after "earth truth" were surrounded.

Mineralogy had long preceded Geology as a science, and the early geologists and founders of the Geological Societies were principally chemists and mineralogists who associated for the purpose of mutual improvement in mineralogy, and as mineralogy as a science owes its existence mainly to the miner, it is not surprising in a county such as Cornwall, whose minerals must have been a subject for investigation from the earliest civilised times, because of the peculiar mineral wealth of the county and the supreme importance of tin in the manufacture of bronze, that a society was early established, as stated in the preface of the first volume of the *Transactions*, "for cultivating and diffusing a knowledge of Mineralogy and Geology in a district so inexhaustibly rich in all the various treasures of the mineral kingdom, and so singularly adapted, both from its natural structure and artificial excavations, for the examination of subterranean phenomena."

Sir Archibald Geikie, in his Presidential address at the centenary celebration of the Geological Society, referring to this subject, observed: "It has been said that the geologist ought never to forget that the mineralogist was his father. The study of minerals always preceded that of rocks; and it should always be remembered that the early mineralogists were in fact the first geologists by whom the petrographical divisions of geology were laid. But if the geologist is to own the mineralogist as his father, he must surely acknowledge the miner to be his grandfather. For many centuries, and long before the use of scientific mineralogy, most of the current knowledge of the nature and disposition of the

minerals and rocks of the earth's crust sprang out of the labours of those engaged in mining operations. It was the business of those men to make themselves practically acquainted with the subject, so far, at least, as regarded the facts that had to be attended to in the sinking and working of mines. As a rule, however, they did not trouble themselves with explanations or speculations as to the origin of the rocks with which they had to deal, and when they did so they usually attained to no greater measure of success than other theorists before them."

Many of the miners of Cornwall in those bygone times, though they have left no written record behind, must have been observers, and must have put their observations to the test of actual experience. A treatise on the occurrence of tin by a master miner of those fable-clouded days might be somewhat crude and startling in its generalisations, but the very primitiveness of its ideas might give some of the dignified scientists of later times a lesson in simplicity and directness, so far as the recording of simple facts was concerned, and might have proved an extremely interesting document in the study of primitive psychology. To-day, however, I purpose to deal not in shadowy speculations on the "might have been," but on the many workers who within the last two centuries have by patient labour and diligent record built up both the substructure and the superstructure of Cornish Geology, and especially on those who are still strenuously engaged in amplifying and consolidating and clarifying that magnificent wealth of detail with regard to this fascinating subject that comes to us as a legacy from the mighty workers of the past.

To give a complete account of all the workers in this wonderful field is obviously impossible, as others no doubt have speedily discovered who have approached the task; but I should like my endeavours to be regarded more as a tribute to the workers, and to the work they have done, than an attempt to present in historical succession the many who have participated in bringing our knowledge of Cornish Geology to its present condition.

In Volume V of the *Journal of the Royal Institution of Cornwall* is a formidable list of workers and works "On the Geology, Mineralogy, and Palæontology of Cornwall," by Mr. William Whitaker, of the Geological Survey of England. This list must have a sobering influence on all students who wish to study the literature of Cornish Geology, for it contains the names of no less than 237 authors, and the titles of 654 books, papers, maps, etc., ranging from the year 1602 to 1873.

First, in point of time, among the publications of purely historical interest is Carew's *Survey of Cornwall*, published in 1602, and so ably referred to and made use of in the address of a former President of this Society, namely, Mr. J. D. Enys. Between 1750 and 1770 the Rev. W. Borlase published a series of geological papers, parts of which still possess a considerable amount of scientific interest. The first of these was "An inquiry into the original state and properties of Spar, and Sparry productions, particularly the Spars or Crystals found in the Cornish Mines called Cornish Diamonds." The title shows the natural scientific bent of the writer's mind, even though the treatment of such a subject lay far behind the scientific equipment of his time. He also published an account in 1757 of the submarine forest at Mount's Bay, and a year later described the raised beach to the south of Cape Cornwall. His papers on the ancient and present states of the Isles of Scilly and his *Natural History of Cornwall* are, however, by far the best known of his works.

The first contribution of genuine scientific value on the mineral deposits of the county was W. Pryce's *Mineralogia Cornubiensis: a treatise on Cornish Minerals, Mines, and Mining*, published in 1778. This important work attracted a considerable amount of attention on the Continent, and was undoubtedly responsible for much of the interest displayed by French and German writers in the mineral wealth and the mining industries of Cornwall. Indeed, if one may judge from the lengthy summaries, notices, and discussions that this book produced in foreign journals, it is doubtful if any subsequent publication, up to the time of De la Beche's *Geology*, brought Cornwall so prominently into

notice among European scientific and mining circles. Just about the beginning of last century, Philip Rashleigh, of Menabilly, published his well-known *Specimens of British Minerals selected from the cabinet of P. R., with General Descriptions of each Article.* The work, which is in two volumes, is illustrated by many coloured plates of the minerals described. At that period the influence of Linné was paramount in scientific circles, and in his remarkable work the author adopts the great Swedish naturalist's binomial system of nomenclature to the mineral world, an innovation that was not received with much favour and was not adopted. Thanks to the public-spiritedness and prompt action of Mr. J. D. Enys, most of the type minerals described in that work, together with the rest of the magnificent Rashleigh collection, are now in the museum of the Royal Institution at Truro.

In 1814 Dr. W. Fitton, in a paper "On the Porcelain Earth of Cornwall," published in the *Annals of Philosophy*, was the first to draw attention to the china clay deposits of the county, and that same year the great geologist, W. Phillips, in the *Transactions* of the Geological Society, published the first really modern account of Cornwall's mines from a modern standpoint. This paper, "On the Veins of Cornwall," dealt more especially with Herland Mine and Wheal Alfred, and was in great part reproduced in his well-known *Geology of England and Wales*, and is frequently quoted with appreciation by geologists of the present day.

In 1818 appeared the first volume of the *Transactions of the Royal Geological Society of Cornwall.* This Society itself had such a stimulating influence on local workers, and drew so many outsiders to the study of the geological problems of the county, that from this point onwards the present student of local geology suffers from embarrassment of riches in published articles and memoirs. It is certainly surprising to find the true grasp of geological structure attained by these early writers, and the papers by Joseph Carne "On Elvan Courses" and "On the Discovery of Silver in the Mines of Cornwall"; Dr. J. Davy's account of granite veins at Porth Just, Cape Cornwall; John Hawkins "On Submarine Mines, with particular reference to the

Wherry Mine"; A. Majendie's "Notes on the Coast, West of Penzance," and "On the Structure of the Scilly Islands"; and Dr. Paris' contribution "On a Recent Formation of Sandstone occurring in various parts of the Northern Coasts of Cornwall," are characterised by most careful observation of detail and accuracy of description. Sir Humphry Davy, Sir C. Hawkins, the Rev. J. Rogers, and others are also contributors.

Four years later, in 1822, the second volume of the *Transactions* appeared, and introduces us to one of the outstanding geniuses of the county, Robert Were Fox, and to at least two others whose names and work are still frequently quoted, namely, Dr. H. S. Boase and Dr. J. Forbes. Robert Were Fox's contribution to this volume is a paper "On the Temperature of Mines," in which he records a series of observations showing a fairly uniform and constant increase of temperature in depth, a subject to which he again returns in Volume III. Most of his smaller papers naturally appeared in the *Reports of the Royal Cornwall Polytechnic Society*, and his larger ones in the *Philosophical Transactions*. Henry Boase's contribution deals with the submerged forest and sandbanks of Mount's Bay, while Dr. Forbes discusses the geology of the Land's End district and of St. Michael's Mount. Dr. Henry S. Boase contributed a paper "On the Tin Ore of Botallack and Levant." Joseph Carne reappears with researches "On the Mineral Productions and the Geology of the Parish of St. Just" and "On the Relative Age of the Veins of Cornwall." John Hawkins is another frequent contributor, and papers from his pen appear "On Some Advantages which Cornwall possesses for the Study of Geology," "On Stratified Deposits of Tinstone called Tin-floors," "On the Nomenclature of Cornish Rocks," "On the Phenomena of Intersected Lodes and the Legitimate Inferences which may be drawn from them," "On the Intersection of Lodes in the direction of their Dip or Underlie," and "Observations on the Alluvial Strata of Porth, Sandrycock, and Pentuan."

In Volume III, published in 1827, W. J. Henwood first appears as a contributor with two unimportant papers "On the

Exudation of Gas in the Union Mines," and "Notice on the Heave of a Copper Lode by a Flucan Vein in the Consolidated Mines, Gwennap"; Dr. Henry S. Boase furnished some observations "On the Alluvial Formations of the Western part of Cornwall," and "On the Sandbanks of the Northern Shores of Mount's Bay"; Joseph Carne treats of Copper Mining in Cornwall, and on the Granite of the Western Part of Cornwall. Interesting papers, though not strictly of geological interest, appear from Dr. Barham, on "Some Arguments in support of the Iktis of Diodorus Siculus is St. Michael's Mount"; by John Hawkins "On the Intercourse which subsisted between Cornwall and the Commercial states of Antiquity, and on the state of the Tin Trade during the Middle Ages"; and by Sir T. S. Raffles "On the Tin of the Island of Banka."

Volume IV, published in 1832, is mainly taken up by Dr. H. S. Boase, who publishes his first account of the Geology of Cornwall as a whole, and accompanies his paper with a rough geological map, the first geological map of the county that appears. This valuable contribution is marked by careful original observations and laborious work, and those who have followed in the same fields have been struck with the accuracy of the detailed descriptions of the writer.

Robert Were Fox published a short paper on "Some Observations on Metalliferous Veins and their Electro-Magnetic Properties," in continuation of a paper which he had previously communicated to the Royal Society on that subject; and J. Hawkins is again to the front with papers "On the Structure and Composition of the Cornish Peninsula," "On the state of our Tin Mines at different periods," "On a Deposit of Alluvial Matter at St. Agnes Beacon," etc. Joseph Carne writes on Stream Tin, and W. J. Henwood furnishes descriptions of Stream Tin ore in Cornwall, with remarks on the Theory of Formation, while the whole of Volumes V and VIII is devoted to his great work on the metalliferous deposits of Cornwall and Devon. The value of this monumental contribution to our knowledge of the most important industry in the county is too

well known to require any eulogy at my hands. Henwood had ample opportunities and turned them to equally admirable use. Much of the material that he placed on record in these volumes could not have been obtained at a later date because of the mines being closed. In the first part of Volume VI, published in 1841, the Rev. E. Budge deals with the conglomerates and raised beaches of the Lizard district, but by far the most important name in the volume is that of Mr. C. W. Peach, a veritable prince among naturalists. By devoting so much of his attention to investigating the fossils of a county, where organic remains are so poor and badly defined as to make the study of stratigraphical geology supremely difficult, Mr. Peach rendered most signal service to all subsequent geologists. Additional papers from this accomplished palæontologist appear also in Volumes IX and X. In connection with the palæontology of the county it is worth mentioning that Professor J. Phillips published his figures and descriptions of the palæozoic fossils of Cornwall, Devon, and West Somerset in 1841, the same year as Mr. Peach's first paper appeared in our *Transactions*.

In 1844 Jonathan Couch contributes a short note on the red colour of fossiliferous rocks near Looe, while his son Richard Quiller Couch sends the first of an all too short series on the fossil remains of the county. In 1846 Sir Roderick Murchison contributes to the last part of Volume VI "A Brief Review of the Classification of the Sedimentary Rocks of Cornwall," and S. R. Pattison a paper "On the Carboniferous System in Cornwall," which he follows up in later volumes by other papers of stratigraphical interest.

In Part II of the seventh volume there is the first of a series of papers by Mr. J. Giles "On the Geology of the Liskeard District," and in addition the first paper published by the great Devonshire geologist, William Pengelly. In 1852 there appeared in Volume VII a short paper by W. Whitley "On the Effects of Geological Structure and the Action of the Waves on the Geographical Outline of Cornwall." This prolific writer made many contributions to the geology of the county, the great

majority of which, however, appeared elsewhere. In 1858 and still in Volume VII Augustus Smith, the Lord Proprietor of the Isles of Scilly, writes on the chalk flints and greensand fragments found in Tresco. In the following year Mr. J. Jope Rogers treats of the strata of the Cober Valley.

The long drawn out Volume IX, begun in 1864 but not completed till 1875, contains two papers by Miss E. Carne, daughter of Mr. J. Carne, already referred to. The first of these is "On Transition in Metamorphoses of Rocks in the Land's End District," and the second, "Inquiry into the nature of the Forces that have acted on the Formation and Elevation of the Land's End Granite." Messrs. A. T. Davies and Benedict Kitto contribute a paper on "Some beds of Sand and Clay in the parish of St. Agnes."

The volumes from ten to thirteen, covering the period of 1879 up to the present, are naturally the most interesting to students and the most generally read. They of course include a considerable amount of literature dealing with the remarkable discovery of pliocene beds at St. Erth, the only fossiliferous deposit of this age yet found in the county. These beds were discovered in 1882, and their determination as pliocene was the last work of Mr. Searles V. Wood, junior, famous for his publications on the pliocene crag deposits of the eastern counties, who died shortly before the publication of his paper in 1885. This deposit received most careful attention at the hands of Messrs. Robert G. Bell and P. F. Kendall, and of Mr. Alfred Bell. An important paper by the first-named geologist appears in Volume XI, and the most complete list of the fauna in Mr. A. Bell's lengthy paper in XII. A beautiful series of papers on the Foraminifera of these St. Erth beds has been published in Volumes X to XII by Mr. Fortescue W. Millett, late of Penzance but now of Brixham. In these later volumes there is a great deal of most excellent work by the two most eminent resident geologists of the present time, Mr. J. H. Collins and Mr. Howard Fox.

A great landmark in the history of Cornish Geology was the publication of Sir Henry de la Beche's "Report on the Geology

of Cornwall, Devon, and West Somerset," in 1839. This grand memoir is one of the most luminous of the early contributions to British Geology, and even after a lapse of nearly seventy years, during which the Science of Geology has advanced from infancy to mature manhood, it is still the standard work of appeal for the South-West of England—a most eloquent testimony to the accuracy of the author's facts and soundness of his geological reasoning.

Once more the labours of Cornish geologists, both small and great, are being built up into a magnificent and orderly whole, and on still surer foundations, by an enthusiastic band of skilful workers, whose personal labours are doing so much to corroborate and amplify the results already achieved.

On the 26th August, 1896, at the joint meeting of the Cornish Scientific Societies held in the Hall of the Royal Cornwall Polytechnic Society at Falmouth, it was unanimously resolved, "That a Committee consisting of the presidents and secretaries of the several Cornish Societies, with power to add to their number, be appointed for the purpose of securing a re-survey of the county, by the officers of the Geological Survey of Great Britain." This Committee memorialised Sir Archibald Geikie, the Director-General of the Survey, to this effect. The memorial was favourably received, and within twelve months a re-survey had been initiated. When Dr. Teall succeeded to the Directorship of the Survey in 1901, he appointed Mr. Clement Reid Geologist in charge of the re-survey of the county. Mr. Reid and his staff have been hard at work in Cornwall ever since, and the prints of their labours are now in process of appearance. The new geological maps for Newquay, the Land's End district, Falmouth and Truro, and the Isles of Scilly are already in circulation, together with the memoirs on these respective districts, while the others are in course of rapid preparation. The accompanying memoirs for the Newquay district have been written by Messrs. Clement Reid and J. B. Scrivenor; for the Land's End district by Messrs. Clement Reid and J. S. Fleet; for Falmouth and Truro and Mining district of Camborne and Redruth by

majority of which, however, appeared elsewhere. In 1858 and still in Volume VII Augustus Smith, the Lord Proprietor of the Isles of Scilly, writes on the chalk flints and greensand fragments found in Tresco. In the following year Mr. J. Jope Rogers treats of the strata of the Cober Valley.

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A great landmark in the history of Cornish Geology was the publication of Sir Henry de la Beche's "Report on the Geology

Messrs. J. B. Hill and D. A. McAlister; and the Isles of Scilly by Mr. G. Barrow.

As I have already pointed out, the *Transactions of the Royal Geological Society of Cornwall* are in themselves a fitting record of geological work and progress in the county during the last ninety years, and the short time spent in turning over the pages of its twelve or thirteen volumes with you to-day may not be altogether unprofitable. As science advances the labours of the early workers are liable to be forgotten, and when one sees finished productions like the recent Geological Survey memoirs, one seldom realises that they represent not simply the achievements of the skilled members of the Survey, but the collective endeavours of many generations of earnest men, struggling after the truth in the dim light of uncertain generalisation, and of a knowledge that was too diffuse to be capable of being systematised. The members of the Survey are always most anxious to give full credit to the workers that preceded them, but their object is naturally to present the present condition of their knowledge, and not to give a tedious historical account of the vague and uncertain steps by which the achievement of that knowledge was made possible in the past.

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REPORT OF THE COUNCIL

To the Annual General Meeting, October 29th, 1907.

THE Council are pleased to report to the members that the Museum and Library of the Society are in good condition, and have been visited by a larger number of people than usual during the past year.

The question of the award of the William Bolitho Medal, which was referred to in the report of last year, has received the most careful consideration of the Council, and they now recommend that, subject to the approval of the Trustees of the Society, the medal in future be made in silver-gilt and awarded as an honorary distinction to distinguished men as in the past, and that the surplus income of the fund be distributed in prizes for original papers or work in accordance with such regulations as the Council may decide.

Satisfactory progress has been made with the new geological survey of Cornwall during the year, and the maps of the Isles of Scilly and of the Penzance and Falmouth districts are published and now laid on the table for the information of the members.

The accompanying memoir of the Geology of the Land's End District is also published, and a copy has been received for the Library. The Council regret that this official publication should contain an expression that the mines "are now to a great extent worked out," against which they feel it their duty to make a public protest as inaccurate and liable to do a serious injury to the mining industry of Cornwall.

The Council have awarded the William Bolitho Medal for the year to Mr. Upfield Green, F.G.S., whose work in connection with the Silurian fossils of Cornwall has fully merited the highest distinction in their power. They recommend the election of Mr. Green and Mr. Clement Reid, F.R.S., as honorary members of the Society.

They regret to record the death during the year of two members of the Council, Mr. W. S. Bennett and Mr. A. Bache. Mr. Bennett had been a member for nearly twenty years, and had always been most regular in his attendance and his interest in the welfare of the Society.

Mr. Bache was a new member, having been elected only in 1905, but in the short time had displayed a genuine care in the efficient discharge of his duties.

LIBRARIAN'S REPORT.

1907.

THE Librarian acknowledges, with thanks, the receipt of publications from the following:—

American Philosophical Society.
—— Academy of Arts and Sciences.
—— Geographical Society.
Batavia. Jaarbock.
Bristol Naturalists' Society.
British Association.
Buenos Aires. Museo Nacional.
Buffalo. Society of Natural Sciences.
Canada. Geological Survey.
——. Royal Society.
Cape of Good Hope. Department of Agriculture.
—— Geological Survey.
Colorado Scientific Society.
—— College Studies.
Connecticut Academy of Arts and Sciences.
Cornwall Royal Polytechnic Society.
Denmark. Dansk Geologisk Forening.
Dorpat. Naturforscher Gesellschaft bei der Universitat Jurjew.
Dublin Royal Society.
Edinburgh Royal Society.
Elisha Mitchell Scientific Society.
Geological Survey.
Geological Society.
Geologists' Association.

India. Geological Survey.
Indiana. Academy of Science.
Iowa. Geological Survey.
Japan. Imperial University, Tokyo.
Leicester Literary and Philosophical Society.
Liverpool Literary and Philosophical Society.
—— University.
—— Geological Society.
—— Geologists' Association.
London and West Country Chamber of Mines.
Manchester Geological Society.
—— Microscopical Society.
Maryland Geological Survey.
Malay. Federated States.
Mexico. Instituto Geológico.
Michigan. Academy of Sciences.
Montana. University.
Monte Video. Museo Nacional.
Natal. Geological Survey.
New York Academy of Sciences.
New Zealand. Department of Mines.
New South Wales. Geological Survey.
Normandy. Société Geologique.
North of England Institute of Mechanical and Mining Engineers.
Peru. Cuerpo des Ingeniores de Minas.
Philadelphia. Academy of Natural Sciences.
Queensland Government.
Royal Society.
Saxony. Berg und Huttenwesen.
Smithsonian Institution.
Tuscany. Societa di Scienzi Naturali.
United States. Geological Survey.
Upsala. Geological Institute.
Vienna. K. K. Geologischen Reichsanstalt.
——. K. K. Naturhistorichsen Hofmuseums.
Victoria. Geological Survey.
Western Australia. Geological Survey.

Wisconsin. Geological Survey.
Yorkshire Geological Society.

[*From the Authors.*]

Les Lois fondementales de l'origénie de la terre.
Les Étages et les faunes du Bassin Tertiare du Piémont.
Schisti Cristallini della Alpi.
Sur la Valeur stratigraphique des Lepidochna, etc.
La Reunion Extraordinaire de la Société Géologique de France en Italie, 5–12 Sept., 1905.
Essai schematique de Selenologie.
La Pieghe degli Gneiss Tormaliniferi. By Dr. F. Sacco.
Alkali, etc., Works Acts: Reports 1905–6. Chief Inspector.

[*Purchased.*]

Palæontographical Society. Vol. lviii.
London, Edinburgh, and Dublin Philosophical Magazine.

CURATOR'S REPORT.

DONATIONS TO THE MUSEUM.

THE Curator acknowledges with thanks the receipt of the following additions to the Museum.

Mr. F. H. UREN :—
Stream Tin with pebbles of Magnetite.
Stream Tin.
Specimens of Tin-bearing Ledge.
Cassiterite in Granite.
From Seward Peninsula, Alaska.
Cassiterite with Tourmaline in Granite.
Cassiterite from Quartz Ledge.
Cassiterite.
From Cape Prince of Wales, Alaska.
Wolfram from East Pool.

Mr. C. D. MCGRIGOR :—
Cerargyrite from Perran.

Mr. M. PAROKSAMY :—
Specimens of Corundum from Hyderabad, India.
Two Bulls carved in Steatite.

Mr. W. BENNETTS :—
Specimens of Silver.
Specimens of Gold.
Specimens of Cinnabar.
From California and Arizona.

Mr. H. FOX :—
Trilobite, Calymene, from Veryan.

THE WILLIAM BOLITHO MEDAL,

which is provided for by a fund bequeathed to the Society for the purpose by William Bolitho, of Ponsandane, in 1895, has been awarded to the following members :—

1896. R. Etheridge, F.R.S.
1897. Howard Fox, F.G.S.
1898. J. H. Collins, F.G.S.
1899. F. W. Millett, F.R.M.S.
1900. Sir C. Le Neve Foster, F.R.S., etc.
1901. Thomas Clark.
1902. Dr. Richard Pearce, F.G.S.
1903. W. A. E. Ussher, F.G.S.
1904. J. D. Enys, F.G.S.
1905. Lady Warington Smyth.
1906. A. K. Barnett, F.G.S.
1907. U. Green, F.G.S.

STATEMENT OF RECEIPTS AND EXPENDITURE FOR THE YEAR 1907.

Dr. *The Treasurer in Account with the Royal Geological Society of Cornwall.* **Cr.**

Receipts.

	£	s.	d.	£	s.	d.
October 30th, 1906—						
To Balance in hand				13	16	8
October 29th, 1907—						
To Ordinary Subscriptions	38	16	0			
,, Subscription per His Royal Highness the Prince of Wales	20	0	0			
,, One Year's Dividend on £1800 Midland Railway 2½ % Debenture Stock, £45, less tax £2 5s.	42	15	0			
,, Sales of *Transactions*	0	17	8			
				102	8	8
				£116	5	4
October 29th, 1907—						
To Balance in Treasurer's hands				£36	8	1

Expenditure.

	£	s.	d.	£	s.	d.
October 29th, 1907—						
By Rates and Taxes	0	8	0			
,, Curator's Salary	42	15	0			
,, *Transactions*, Periodicals, Printing, etc.	15	10	4			
,, Fire Insurance Premiums	2	12	9			
,, Coals and Gas	10	9	11			
,, Sundry Repairs to Buildings	3	16	11			
,, Subscription to the Palæontographical Society	1	1	0			
,, Postages and Petty Disbursements	3	3	4			
				79	17	3
,, Balance				36	8	1
				£116	5	4

PENZANCE, *October 29th*, 1907.

T. R. BOLITHO, *Treasurer.*

W. BOLITHO GOLD MEDAL ACCOUNT.

Dr.	£	s.	d.	Cr.	£	s.	d.
November 10th, 1906—				October 30th, 1906—			
To Gerrard and Co. for Medal, "A. K. Barnett"	12	10	0	By Balance	529	9	1
October 29th, 1907—				October 29th, 1907—			
To Balance	536	19	10	By Interest to date	20	0	9
	£549	9	10		£549	9	10
				October 29th, 1907—			
				By Balance	536	19	10
					£536	19	10

LIST OF PAPERS

READ TO AND PUBLISHED BY THE SOCIETY.

1907.

President's Address. By A. K. Barnett, Esq., F.G.S.

Trilobite in the Veryan Quartzite. Read by Howard Fox.

On the Occurrence of Trees and Vegetable Remains in the Stream Tin in Cornwall. By Rev. D. Gath Whitley.

TRILOBITE IN THE VERYAN QUARTZITE.

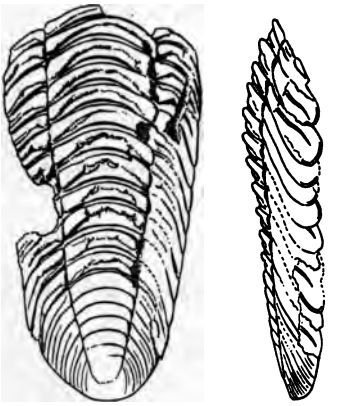
By Howard Fox, F.G.S.

(Read 29 October, 1907.)

I have the pleasure of presenting to your Museum the first specimen of a large trilobite as yet recorded as found in the Veryan quartzite.

I received a letter last December from Mr. Frank Peters of Carne, Veryan, saying that he had met with a fossil whilst quarrying the quartzite near his cottage, and which he offered to give me. I went to Carne and Mr. Peters showed me the exact spot in a small quarry 50–60 yards south of his cottage from which he obtained it, viz. from the base of a mass of darkish quartzite some 15 feet high. It is the first fossil of any kind that he has noticed during his work on these rocks, which has been occupying him for the last few years. I sent the fossil to Mr. Clement Reid, F.R.S., who had just finished his official Memoir on the district. Mr. Reid showed it to Mr. Philip Lake, our best authority on Lower Palæolithic trilobites, and asked him to describe it. This Mr. Lake has kindly done in the

following description which he has accompanied by the annexed sketch.



NATURAL SIZE

In the *Summary of Progress* of the Geological Survey of the United Kingdom, 1905, Mr. Reid writes, at page 24 :—

"Many years ago Mr. C. W. Peach found in the Gowan area a certain number of fossils considered to prove the Caradoc age of the quartzites; on their authority an ill-defined area has long been coloured Lower Silurian on the maps. The bractiopods found by the Survey and mentioned in the last *Summary* were clearly of Lower Palæozoic type; but during 1905 Mrs. Reid found on the beach masses of a peculiar fine-grained iron-grey rock full of detached segments of trilobites. The rock proves to be a thin band probably only six inches thick, not yet found in place, but met with adhering to a fallen block of fossiliferous quartzite containing numerous specimens of *Orthis calli-*

gramma. This thin band yields a trilobite fauna of seven or eight species. It also contains several species of *Orthis*, but scarcely a trace of other fossils. Its exact age will be discussed in the Memoir of the district."

NOTE ON A SPECIMEN OF CALYMENE FROM VERYAN.

BY PHILIP LAKE, M.A., F.G.S.

The specimen here described was found by Mr. Frank Peters in the quartzite of Carne, Veryan, and is the first trilobite which has been found there. Unfortunately it lacks the head, but the tail and thorax are nearly complete; and as the state of preservation is good, the specimen is worthy of a figure and a brief description.

The first segment of the thorax is entirely absent, or concealed in the matrix; of the second a faint trace can be seen; the remaining eleven are all distinctly visible, although some portions are broken away or are buried in the rock in which the specimen lies. The axis is broad, forming in the anterior segments more than one-third of the total width, much narrower proportionally in the hinder segments. The pleurae are bent strongly downwards and somewhat backwards at the fulcrum, which is placed very near to the axis; they are deeply grooved, strongly faceted, and rounded at the ends.

The tail is very convex, rounded in outline both in front and behind. The axis is conical, forming about one-third of the total width, not at

all prominent and not reaching to the posterior margin; probably consisting of about eight rings, of which six are preserved. The lateral lobes are arched downwards and bear six ribs, which are interlined throughout and are bent obliquely backwards as well as downwards.

Owing to the absence of the head it is impossible to determine with certainty the species to which this specimen belongs. It agrees, however, so far as it goes, with *Calymene cambrensis* Salter, and if not identical, is at least a closely-allied form. *Calymene cambrensis* is a characteristic species of the Llandeilo Flags of Wales. Mr. Fearnsides, however, has found a very similar form in the "Calymene Ashes" of Llyfnant, which belong to the Arenig series. With the material at present available it is impossible to distinguish between the Llyfnant form, the Veryan specimen, and Salter's *Calymene cambrensis.* So far, therefore, as this trilobite affords us any evidence, all that we can say is that the Carne quartzite belongs either to the Arenig or the Llandeilo series. The somewhat similar quartzite of Perhaver contains several species of trilobites and may be placed, with some degree of certainty, either in the Llandeilo series or at the top of the Arenig.

ON THE OCCURRENCE OF TREES AND VEGETABLE REMAINS IN THE STREAM TIN IN CORNWALL.

By Rev. D. Gath Whitley.

The variations of climate during the past history of the earth form one of the most interesting and one of the most difficult subjects which the geologist has to consider. Sir Charles Lyell has devoted a considerable space in his greatest work to the discussion of the question,[1] but fresh facts have been brought to light since he wrote his valuable chapters. The existence of immense deposits of coal in the very heart of the Arctic Regions, as well as fossilized trees, coral limestones, and reptilian remains, all prove undoubtedly that in former ages the Polar Regions had not merely a warm, but even a tropical climate. The talented Swiss botanist, Professor Heer, has even maintained that in the Miocene Period a vigorous vegetation covered the North Pole itself.[2]

In Cornwall, although our Primary Rocks abound in fossils, the evidences as to climate are but doubt-

[1] *Principles of Geology*, tenth edition, vol. i. pp. 174–305.
[2] *Flora Fossilis Arctica.*

ful. The limestone patches favour the idea of a warm climate, while the traces of a Glacial Period, referred to by the Government geological surveyors, show a period of cold, which must have been followed by a milder era, which ushered in the climate possessed by Cornwall in the present day. The fauna of the Pliocene deposit at St. Erth also shows how varying has been the climate of Cornwall, and that a steady refrigeration has taken place in our climate from the middle of the Tertiary Period down to the present order of things.

This paper is concerned, however, only with Cornwall at a very recent geological era, and it refers to that epoch in the condition of our county, which is included in the term Quaternary Period. This phrase may be said to include all the time which elapsed between the end of the Pliocene Period and the dawn of the Historical era. The term Quaternary, as applied to this epoch, is not quite satisfactory, as it is complicated by the occurrence of the Glacial Period; still, as I have tried to show in a paper read before this Society,[1] I consider that it may be retained. Nevertheless, I would substitute for the phrase Quaternary Period the term Mammoth Period, which I think is less open to objection. The Mammoth lived from the end of the Pliocene Era, right down to the beginning of the Neolithic Age, and was,

[1] *Transactions of the Royal Geological Society of Cornwall*, Part IX, vol. xii. 1904, pp. 761–773.

without doubt, the principal animal of the epoch. In Cornwall no remains of the Mammoth have been certainly discovered, for I cannot attach any importance to the vague reports which from time to time have been circulated as to the finding of its remains. In Devonshire, on the contrary, the fauna of the Mammoth Period is shown in the caverns of Kent's Hole and Brixham, and in the ossiferous fissures at Oreston, Cattedown, and Plymouth Hoe.

I follow the old opinion, which declares that in Cornwall the deposits of the Mammoth Age consist of the sands and clays of Crousa Downs and St. Agnes Beacon, the Raised Beaches, the Stream Tin deposits, and the Head of Rubble, which, in addition to the beds of consolidated sand, covers so many of our Raised Beaches.

Now, so far as the Mammoth Period is concerned, the contemporaneous fauna in Devonshire, as exhibited by the mammalia, gives us valuable information as to the climate of Cornwall at that time. The leading mammals in Devonshire in those days were the Mammoth, rhinoceros, lion, elk, buffalo, cave-bear, and hippopotamus. Now the presence of the last is decisive. In the Head all along the southern English coast the bones of the hippopotamus are found, and they occur in the Gower caves in South Wales, the fauna of which is, according to Sir Joseph Prestwich, the same as that of the Head.[1]

[1] *Quarterly Journal of the Geological Society*, vol. xlviii. 1892, p. 322.

He further states that the Stream Tin beds of Cornwall belong to the "Rubble Drift,"[1] and this "Rubble Drift" in the south of England contains the bones of the hippopotamus. If then the hippopotamus lived in Devonshire during the Mammoth Period, it is plain that at that time it must have inhabited Cornwall also, and this is a convincing proof that at the time when our Cornish Stream Tin beds were formed a mild and warm climate prevailed in Cornwall. Moreover, the fact that such an abundant mammalian fauna lived in Devonshire during the Mammoth Period (i.e. Quaternary Era) also shows that there was an exuberant vegetation both in Devon and Cornwall at that time. The winters must have been mild, and Cornwall at that time, with its coasts warmed by the Gulf Stream, must have had a climate warmer than it possesses at the present day.

The flora of a country, however, taken as a whole, is the best test that can be applied to determine its climate, and that test I propose to apply, as far as possible, to the deposits of the Mammoth Age in Cornwall.

I have for a long time pursued this investigation, and for some years have examined the various needful districts in our county. I have especially talked with the old tin streamers and miners, and have had most valuable information given to me by residents in the districts. For sections I have

[1] *Quarterly Journal of the Geological Society*, vol. xlviii. 1892, pp. 317, 342.

principally relied on those given by Mr. William Jory Henwood, published in the *Transactions* of this Society, and also on his addresses delivered to the Royal Institution of Cornwall during the term of his Presidency. I acknowledge also my indebtedness to the valuable papers of Mr. J. H. Collins, and also to the most able assistance and interesting information given to me by Mr. W. J. Millett of Roche.

In this discussion I use the term "Tin Ground" to signify the detrital deposit *only* in which the tin occurs—that is to say, the genuine Stream Tin bed. This is absolutely necessary since in talking with the old miners I often fell into mistakes, as they sometimes included in the Tin Ground the earthy deposit lying above it, called the Overburden. The relative age of the two beds is still a matter of dispute, no animal remains having ever been found in the genuine Stream Tin gravels in Cornwall, but they have been discovered in the overburden which lies *over* them, especially at Carnon and Pentuan. These remains were those of typical Neolithic animals, the great Palæolithic mammalia, such as the Mammoth and rhinoceros, being always absent.

The vegetable remains in the Tin Ground in Cornwall consist of three distinct characters. *First*, black earthy mould and peat formed from vegetable decay. *Secondly*, fragments of wood, nuts, acorns, etc. *Thirdly*, large trees either standing upright or lying prostrate. All of these indications deserve a brief notice.

All over England, France, and Belgium it is a very common thing to find the Quaternary clays and gravels full of black stains, marks of leaves, and indications of vegetable mould, whilst fragments of wood occur in these deposits in great numbers.

Precisely the same thing occurs in our Cornish Stream Tin deposits, and particularly in that mass of rubble which lies above them. When Mr. Carne, before this Institution, propounded his theory of the Diluvial origin of the Stream Tin beds,[1] Mr. William Jory Henwood was unable to accept the explanation. The rubble which lay *over* the Tin beds was, in Mr. Henwood's opinion, the *real* Flood deposit because it was full of nuts, vegetable remains, and fragments of trees.[2] The old miners who have streamed for tin for the greater part of their life have often told me that in the *real* tin beds they have found no vegetable remains, but they have met with them in great quantities in the *overburden.* To this rule, however, there are many exceptions, some of which I will now proceed to enumerate.

The old streamers who have worked the Tin Ground in the Tregoss Moors have again and again declared to me, or to my informants, that they have often found among the tin gravel nuts in large quantities, and in addition to these they found, from time to time, fragments of oak as thick as a man's thumb. These fragments, which were evidently portions of the branches torn off from the trunks of

[1] *Journal of the Royal Geological Society of Cornwall*, vol. iv. p. 55. [2] *Ibid.*, vol. iv. p. 68.

large oak trees, lay in the genuine beds of Stream Tin. The same thick accumulation of nuts has frequently been found in the Stream Tin gravel in the Luxulyan valley, and in a stream-work in the upper part of the valley of the Fowey a deposit of peat was discovered lying between two layers of Tin gravel. Near Mevagissey in the Tin deposit, so much black oak wood was formerly found that a man made walking-sticks from it; this was about sixty years ago. In the Cober valley near Helston leaves lay on the Tin ground, but the exact position of this leafy bed seems to be a little uncertain.

It appears, therefore, that at the time of the deposit of Stream Tin in Cornwall the land surface of the county was denuded by powerful currents of water which tore up the surface and mingled together in one confused mass, grass, vegetation, twigs, and branches, burying them amidst gravel and earthy débris.

But from time to time prostrate trees of large size have been found in our Cornish Tin beds, actually present amidst the Stream Tin gravels. Every one knows that trunks of trees have been discovered in large quantities in the rubble *over* the Tin ground, but to these I do not refer, and I especially limit my remarks to those trunks and fragments of trunks which have been found in the Tin gravel itself.

Some time ago, in cutting a deep ditch on the Bodmin Moors near Dosmery Pool, fragments of oak trees of a considerable size were found in the peat.

As, however, no depths or details of the section were given, these might have been of a later age than the real Stream Tin deposits, but there seems to be no doubt about the authenticity of the next case to which I shall refer.

The Stream works in the Bodmin Moors were formerly very important, and in the Tin beds which were connected with them trees were frequently discovered; the heads of these trees were generally turned down the valleys, as if they had been overthrown by a sudden and violent flood coming from the north. In one of the works for Streaming Tin in the upper part of the valley of the Fowey, a large tree was found in the genuine Tin ground. It was lying when discovered in a layer of peat between two beds of Stream Tin. The tree was lying flat, and was 28 feet long and 10 inches in diameter.[1] Evidently the rush of water which brought this tree into the position it occupied must have been of a very violent and tumultuous character, as it was powerful enough to root up, break in two, and carry along so large a tree. I imagine that the peaty layer in which the tree lay was not a genuine peat formed by slow growth, such as lies above the Stream Tin beds in the Tregoss Moors, but was merely the wreck of the vegetable soil torn up by the tumultuous waters at the same time that the tree was uprooted. It was, in fact, the vegetable mould of the forest. Horns of deer

[1] *Journal of the Royal Geological Society of Cornwall*, vol. vii. pp. 35, 36.

are said to have been found in this peat, but I am not acquainted with any details.

In the Luxulyan valley vegetable mould has been constantly found mingled with the tin gravel, pointing to a destruction of a forest soil at the time of the formation of the Stream Tin. So powerful, indeed, was the rush of water that deposited the beds of Stream Tin in the Luxulyan valley that it was able to carry along enormous blocks of quartz 15 feet square, and to bury them pell-mell amidst the tin gravel.

At Cotton Wood on the Camel, in the parish of Bodmin, a very important discovery was made some time ago. The deep bed of tin existed here close to the foot of the hills on the south side of the valley. The tin gravel was 15 feet deep, and its bottom was 50 feet below the surface of the ground. Embedded in the tin gravel was the trunk of a large oak tree. It was 12 feet long and 17 inches thick in the largest part. The wood was hard and black, and there were no roots or branches. This fragment of an oak tells the same tale as that found in the Stream Work on the Upper Fowey.

The flood that deposited the Stream Tin in the valley of the Camel was of such a violent and powerful character that it tore up a great oak tree more than 2 feet in diameter at its base, broke the trunk into fragments 12 feet in length, and, tearing off the branches by its fury, buried a part of the trunk deep in a mass of earthy rubble, which,

when deposited, formed the layer of Stream Tin.[1] Sir Roderick Murchison, when informed of this discovery, declared that the deposit of Stream Tin seemed to him to be like the gold gravels of Australia. If this parallel be correct, then it furnishes us with an important link in the chain of evidence which establishes the geological age of our beds of detrital tin. The auriferous gravels of Australia, as well as those of California, are generally considered to be the product of vast denudations which occurred during the Quaternary Period, and our Cornish Stream Tin deposits are with good reason referred to the latter part of the same geological era.

There is now to be considered another class of vegetable remains in our beds of Stream Tin. That is *upright trees*, which have been found *standing erect* in the tin ground quite dead, but in a perfect state of preservation. The elaborate sections of the alluvial deposits at Pentuan given by Mr. Colenso[2] show that an ancient forest, principally of oak trees, grew *over* the tin deposits. There are, however, old tin miners still living who have given much additional information of a somewhat different nature. According to them the trees were growing up *through* the tin ground, having their roots below it. From this, therefore, it would appear that the force of the flood which deposited

[1] I am indebted to the kindness of Mr. W. J. Millett, of Roche, for this interesting fact.

[2] *Transactions of the Royal Geological Society of Cornwall*, vol. iv. p. 30, etc. etc.

the tin gravel was in a great measure spent before it reached the place where the trees grew. For, although it was powerful enough to break them, it had not sufficient force to root them up and transport them.

It appears, then, that we may divide the vegetable remains in the Cornish Tin deposits as follows: *First*, mould, leaves, nuts, and branches. *Secondly*, large trunks of trees lying prostrate and stripped of their branches. *Thirdly*, trees standing upright with their roots in the natural position, but without branches, and broken off some distance above the roots.

Our Cornish Stream Tin beds have often been said to have been formed in an Arctic climate. It is maintained the severity of an Arctic frost shattered the rocks, and when the snow-beds melted, the water derived from their melting poured into the lower grounds and deposited the stony débris rich in stanniferous elements, which we call Stream Tin.[1] I cannot accept this theory. The term "Arctic climate" is so vague that it may mean a climate in the Polar Sea, or one two thousand miles to the south. An Arctic climate, also, would cause the rivers to be frozen in winter, but this could not have happened in Cornwall at the time of the deposition of the Stream Tin, for the hippopotamus then lived in the West of England. Nor would the *slow* and *gradual* melting of snow-beds provide an aqueous

[1] *Memoirs of the Geological Survey of England and Wales*, 1907. *The Geology of the Country near Newquay*, p. 69. See also *Prehistoric Europe*, by Professor J. A. Geikie, p. 228.

force powerful enough to carry along the huge blocks of quartz which are constantly found in our Stream Tin deposits. I am aware that an attempt has been made to establish an Arctic climate in Cornwall from the occurrence of the Arctic Willow (*Salix Polaris*) and the Dwarf Birch (*Betula Nana*) in the Quaternary Beds at Bovey Tracey.[1] But these trees are too often found now, and in the Neolithic deposits of Great Britain, amidst the remains of a Temperate flora, to warrant such a conclusion.

Every one who is at all acquainted with the beds of the Mammoth Period in Great Britain knows how often they contain remains of vegetation, for even in such a genuine glacial deposit as the Boulder Clay, fragments of the trunks of trees are frequently found. Amidst the Quaternary deposits of England, deposited during the Mammoth Period, lignite, peat, portions of stems and branches, and even trunks of trees are again and again discovered. Sir Joseph Prestwich tells us that in a gravel bed of the Mammoth Age at West Hackney the trunks of the following trees were discovered: oak, elm, hazel, and alder; some of the fragments of the trunks were from three to four feet long, and from six to twelve inches in diameter. They were lying prostrate, and were accompanied by leaves and fragments of small branches.[2] From the complete absence of roots it seems certain that they

[1] *The Geological Magazine*, vol. i. 1884, p. 132.
[2] *Quarterly Journal of the Geological Society*, vol. xi. pp. 107–10.

were drifted, and did not grow on the spot. Just exactly, also, as we so often find in our Cornish tin beds, the force of the current which deposited the drift was so great that the trunks of the trees were broken into short fragments and the branches torn off. Considerable light has been thrown on the flora of Cornwall in the Mammoth Period by the researches made in the Quaternary Beds at Hoxne in Suffolk by a committee appointed by the British Association.[1] Here, in a hollow formed in the Boulder Clay, a number of sand and clay beds were discovered full of plants and trees similar to those now growing in Great Britain. In the midst, however, was a stratum containing plants of a more northern character, such as the Dwarf Birch and the Arctic Willow. The Temperate flora in the accompanying beds included such trees as the oak, ash, cornel, elder, and alder. The whole deposit seems to have been continuous, and formed in a lake, while the Mammoth Period appears to have been too short to warrant the conclusion that it was characterized by fluctuations of climate.

Another remark I would make before passing on, on the testimony of the forest vegetation. As far as we can ascertain the forests of Cornwall during the Mammoth Period were of exactly the same nature as those which have been brought to light in the discovery of our Submarine Forests of the

[1] *Report of the British Association*, 1896, pp. 400–16. See also *Proceedings of the Royal Society*, 1897, vol. lxi. p. 40; and *The Ancient Stone Implements of Great Britain*, by Sir John Evans (2nd edition), p. 577.

Neolithic Age, which are so common around our Cornish coasts. The presence of so many large oaks in our peat and gravels of the Mammoth Period, and which have been found in situations and on heights which would now be considered most unfavourable to their growth, indicates the prevalence of somewhat warmer summers at the time when our Cornish Stream Tin beds were deposited.

Enormous trees are found in the Quaternary deposits of Northern France. The peat at the bottom of the valley of the Somme, which belongs to the Mammoth Period, is full of trunks of trees, with flattened branches, and with the remains of various shrubs. Trees, such as oaks, birch, hazel, firs, and yews, are being continually found along the beaches of Northern France. These have been washed up from Quaternary deposits, and they show what the vegetation of Cornwall was during the Mammoth Period.[1] These trees are often larger than any of the same kind growing in the North of France at the present time. In addition to these trees derived from marine peats, the clays of the Mammoth Period in Northern France contain lignites which are sometimes nearly a foot thick.

Striking resemblances to our Stream Tin deposits seem to me to exist in the great Quaternary beds which have been accumulated in vast basins on both sides of the Ural Mountains. Since the publi-

[1] *Esquisse Géologique du Département de la Somme*, by C. J. Buteux, pp. 84, 85.

cation of Sir Roderick Murchison's grand work[1] the geology of this mountain region has been much studied. The glaciation of the northern part of the Ural chain is now generally admitted, but there is still some doubt as to whether the central portion of the chain was glaciated. Along both flanks of the Urals there are extensive depressions which are now filled with Quaternary deposits of the Mammoth Period. These deposits strikingly resemble our Cornish Stream Tin beds, and are supposed to have been formed by the silting up of ancient lakes. Sections show that these deposits consist of two layers, clay and sand at the top, and shingle or coarse gravel at the bottom; the latter bed answering to our Stream Tin, and generally containing —like the Stream Tin in the valleys of Cornwall— considerable quantities of gold.

In this coarse auriferous gravel trees are constantly discovered. The trees are often converted into hornstone, and lie alongside of the remains of the Mammoth. They did not grow where they are found, but were washed along with fragments of rock and gravel.[2]

It is interesting to note that in these Quaternary beds along the flanks of the Ural Mountains, the bones of the Mammoth, the *Rhinoceros*, *Tichorhinus*, and the *Bos Urus*, much broken up and shattered, are found not only in the coarse shingle at the

[1] *The Geology of Russia in Europe and the Ural Mountains*, by Roderick Impey Murchison, Edouard de Verneuil, and Count Alexander von Keyserling. 2 vols. 4to.

[2] *Travels in Siberia*, by Adolf Erman, vol. i. p. 174.

bottom of the deposit, which corresponds to our Stream Tin, but also in the *overlying* beds of clay and silt.[1] At this time the trees were washed into the deposit and the gold was also introduced. Thus, in the words of Sir Roderick Murchison, "Gold was one of the most recent mineral productions in these (Uralian) regions, anterior to the historic era."[2] As the main axis of the Ural chain is granitic, with Palæozoic deposits lying on its flanks, the resemblance of the Uralian Mammoth beds to our Stream Tin deposits is very striking. As to the gold, it was at first found in alluvial gravels, but at present the most profitable Uralian gold workings are on quartz veins. These traverse a rock locally termed Beresite, which Professor Milne says is granitic,[3] although Erman calls it a kind of gneiss.[4] The shattering of the granite rocks, and the distribution of the detritus by aqueous agencies, formed the gold-bearing gravels of the Urals. This is the manner in which, according to the Government surveyors, our Cornish Stream Tin deposits with their gold grains were formed.[5]

In Siberia, Quaternary deposits of the Mammoth Age occur in most of the valleys, and even on the table-lands. These are full of the trunks of shattered trees. In an earthy deposit of the Mammoth Age, six hundred feet above the river Lena, large

[1] *Geology of Russia and the Ural Mountains*, vol. i. p. 494.
[2] *Ibid.*, vol. i. p. 475.
[3] *Geological Magazine*, September, 1877, p. 393.
[4] *Travels in Siberia*, vol. i. p. 269.
[5] *Report on the Geology of Newquay*, p. 69.

quantities of drift-wood were found by M. Stadling, who says that this deposit rested on *solid ice* as clean and blue as steel, and of unknown depth.[1] The same talented traveller tells us that on the dreary plains of Northern Siberia he found ancient drift-wood in an earthy bed of the Mammoth Age, which also rested on *pure ice* of unknown thickness.[2] In the earthy beds of the Mammoth Age in Northern Siberia, fossilized trees lie in such numbers that the natives in these regions never think of using any other fuel. They obtain this fuel on the shores of lakes, which are continually throwing up trunks of trees from the bottom. At times, also, these Siberian Quaternary beds contain, exactly as do our Cornish Stream Tin deposits, trees standing upright, with the roots and branches perfect, but quite dead. In the New Siberian Islands in the Arctic Ocean, which are full of such vast quantities of the bones and tusks of Mammoths and rhinoceroses, trunks of trees, either standing upright or lying prostrate, occur in countless numbers.[3] All these trees belong to the Mammoth Period, and, as in the present day the extreme northern limit of trees is nearly two hundred miles *to the south* of the New Siberian Islands, it is plain that in the Mammoth Age the climate of Siberia must have been much milder than it is now.

All this evidence concerning the flora of Northern Europe and Asia in the time of the Mammoth

[1] *Through Siberia*, p. 161. [2] *Ibid.*, p. 209.
[3] *Geographical Journal*, May, 1894, p. 410.

seems to me to clearly establish three important conclusions :—

First. During the Mammoth Age a mild climate prevailed over *all* the northern parts of Europe, Asia, and America. We have evidence that in Arctic America this climate was so genial that great trees grew in what is now the heart of the Arctic Regions. The Mastodon inhabited the regions around Klondyke, and the Mammoth not only lived in what are now the frozen wastes of Alaska, but actually roamed as far north as Point Barrow, which is the extreme northern point of continental America. The cause of this mild climate is to be found in the existence of large inland seas, which in the Mammoth Period spread over vast areas in Northern Europe and in Central Asia. The Desert of the Sahara at that time did not exist, but the whole of Northern Africa, as far south as the Central Sudan, was a fertile and well-watered region. The mild climate thus created extended in the Mammoth Period over Cornwall.

Secondly. The vegetation of Cornwall during the Mammoth Age was of a *mixed* character, for the flora of the time showed that remarkable blending of types so characteristic of the fauna of the period. The vegetation along the French shores of the English Channel, as well as in the valley of the Seine in the Mammoth Age, gives us an idea of what was the flora of Cornwall in Quaternary times. Oaks, yews, birches, firs, beeches, and willows formed the chief trees of our forests, but mingling

with these were many trees which now only grow in warmer climates, such as the fig, the Judas tree, and the Canary laurel. We find the same blending of floral types in certain regions in the Northern Hemisphere in the present time, and especially in South-Eastern Siberia. In the Province of Trans-Baikal the hillsides are covered with flowers from spring to autumn, and the neighbourhood of Nerchinsk is celebrated for its floral treasures, amongst which are lilies, spiræas, and rhododendrons. M. Cotteau says that the upper valleys in the basin of the Amur are called The Garden of Siberia,[1] because no region presents in a limited space such a variety of magnificent flowers, lilies and poppies being the most abundant. Erman, speaking of the mixed flora of South-Eastern Siberia, says: "In spite of the climate, the flora of Irkutsk is richer than that of Berlin, exhibiting the plants of warmer countries intermixed with those of the Arctic Regions. The wild peach of Nerchinsk is a true apricot (*Prunus Armeniaca*) and contains a very agreeable kernel in a fleshless envelope; while, in the very vicinity of these products of a more favoured climate, we find the Siberian stone-pine and the dwarf-birch of the Polar Circle in the highlands. The same holds good with regard to the fauna of the Trans-Baikalian districts. We see the Tunguze, mounted on his reindeer, passing the Buraet with his camel, and discover the tigers of China in the forests where the bear is taking its

[1] *De Paris au Japon à travers la Sibérie*, p. 295.

winter sleep. The appellation of Dauri, or borderers, which the natives of the Government of Irkutsk receive from the Chinese, is not inappropriately bestowed; for it would hardly be possible to point out any other country upon the earth combining such remote extremes of physical character and condition."[1]

It is in the valley of the Amur that many archæologists find that blending of animal types which leads them to think that we have in this region a climate similar to that which prevailed in Europe during the Mammoth Period.[2] This view cannot be completely accepted, for the Amur is frozen for five months in the year, and as the hippopotamus lived in the Mammoth Age, the rivers could not then have been frozen.

Thirdly. At the close of the Mammoth Period a great destruction of forest vegetation took place. It seems as if at that time the land surface was destroyed by violent and rapid denuding agencies, and, as Sir Joseph Prestwich has maintained,[3] its rocks, plants, trees, and animals involved in one common wreck and ruin.

Thus were probably formed our Stream Tin deposits, and the wreck and débris of the forests which flourished in Cornwall at that time have been constantly brought to light in the midst of our beds of Stream Tin, which formerly were such an important source of wealth to our county.

[1] *Travels in Siberia*, vol. ii. pp. 193, 194.

[2] See *Les Cavernes*, by J. Fraipont, pp. 130, 131; and *Le Préhistorique*, by M. G. de Mortillet, p. 466.

[3] *The Ground Beneath Us*, p. 20.

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OF THE

Royal Geological Society

OF

CORNWALL,

INSTITUTED FEBRUARY 11th, 1814.

The Ninety-fifth Annual Report of the Council,

WITH THE

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THE NINETY-FIFTH

ANNUAL REPORT

ETC.

PENZANCE.

1909.

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THE

ANNIVERSARY ADDRESS OF THE PRESIDENT,

ANDREW KETCHAN BARNETT, ESQ., F.G.S.,

To the General Meeting, November 10th, 1908.

GENTLEMEN,—A foreigner unacquainted with Cornwall might be disposed to wonder how it is that this out-of-the-way region provides ample occupation for a Royal Geological Society. Even when he entered the county, and began to look around as he travelled from place to place, he would probably for a time be quite persuaded that, apart from the mode of occurrence of the mineral lodes, there was nothing so extraordinary in the geological features of the county as to require protracted study—nothing, in short, that might not be exhaustively treated by expert observers in a work or two of modest compass.

He would receive with surprise the statement that Cornwall for twenty decades or so has been the goal and delight of geological students; that in the middle of the eighteenth century Heath and Borlase were occupied upon special treatises concerning it; that Sedgwick, professor at Cambridge and the greatest geologist of his day, had come down specially to investigate its petrology and mineralogy, and had devoted to it a special memoir; and that later Sir Henry T. de la Beche had added a monumental contribution to its geological lore, as remarkable for the variety of its recorded facts as for the lucidity and finish of its style. Still more astonishing would it seem to

the unweeting visitor from afar to find that, after all that had been written on the rocks and minerals of Cornwall, there had remained plentiful subject-matter for deeply interesting papers by J. Carne, W. A. E. Ussher, J. A. Phillips, Sir Clement le Neve Foster, and a host of other scientific worthies, including last, but not least, the distinguished members of H.M. Geological Survey now engaged in the remapping of the county.

I think we may safely predict that when the labours of these most recent observers are at an end this unique peninsula, Cornwall, will still offer to the investigator of natural facts and phenomena abundance of fresh and fascinating sermons in stones. It seems to me, indeed, that one of the most valuable results of the present resurvey of the county will be the help and stimulus it will afford to future students of its geological and mineralogical problems. There is, perhaps, no other area in the whole globe that affords within so small a compass a like multitude of features of interest to the lover of Nature, and to the geologist more especially, albeit all its Mesozoic strata—thousands of feet—have been denuded from off the upturned edges of the altered Devonian rocks, and the St. Agnes Pliocene sands and clays and the St. Erth beds are its sole representatives of the Tertiary deposits. It is only after one has lived in Cornwall—has walked across its wide and stony moors, ascended its granite hills, looked from the summit of its sea-cliffs, explored its rugged coast-line, and descended the shafts and wandered along the levels of its mines of tin and copper and lead—that one begins to realize the enormous opportunities for scientific instruction and education that are offered by this sea-girt and remote portion of the west of England.

Such is the infinite variety of Cornwall that I do not conceive it a rash conjecture that when, by the process of marine denudation, the whole of the present eastern region of Great Britain has been planed away, and the west of England is represented by a rocky archipelago, Cornwall will still have charms for the geological student and riddles for the representatives of some such Society as this to read, if so be Cornwall will still be existent

above the sea. This last question is one upon which only our very far distant descendants are likely to be able to pronounce.

The recent geological history of the county, like that of its tin-trade, is a record of ups and downs. The elevation of portions of our sea-coast, as testified by the raised beaches of Perran Bay, Newquay, St. Ives Bay, and in the vicinity of Cape Cornwall and Coverack and Falmouth, and in Gerrans Bay and elsewhere, suggests the possibility that in process of time our borders might come to be considerably enlarged. Sir Charles Lyell, indeed, long ago pointed out (*Principles of Geology*, I, p. 543, 12th ed., 1875) that it can be shown that all the characteristic features in the physical geology of the region of St. Michael's Mount have been retained through nineteen centuries identically as they are now, despite the action of the sea. It might hence, perhaps, be argued that there, even in recent geological times, loss by marine denudation has been compensated by imperceptible elevation of the land. On the other hand, in the existence of submerged forests and stream-tin gravels (see W. A. E. Ussher, *The Post-tertiary Geology of Cornwall*, 1879, p. 45, and *Geol. Mag.*, 1879), we have irrefragable evidence of local depressions in the west of England. Mr. George Barrow (*Mem. Geol. Surv.*, *The Isles of Scilly*, 1906, p. 33) refers to the fact that although the old beach there was elevated at least forty feet, the whole area, in common with Cornwall generally and the south of Ireland and South Wales, was depressed by a comparatively recent subsidence. What increase in the area of the Scilly Isles has taken place within recent times is due to the washing up of fine sand from the shallow sea-floor to the foreshore.

This much is obviously deducible from an examination of the fossiliferous marine beds of St. Erth—that since the Tertiary period, when, according to Robert Bell (*Trans. R. Geol. Soc. Cornwall*, 1886–7), South-West Britain and Western France formed an archipelago, the level of land in the west of Cornwall has been considerably raised. Mr. Bell's opinion was that the St. Erth beds were deposited in a somewhat shallow gulf or

strait occupying at least the valley in that district, and connecting the northern and southern seas of Cornwall until a comparatively recent period. Whether in the immediate geologic future there are to be movements of elevation in excess of movements of depression in the west of England it is impossible to prognosticate. If we may accept the view of some geologists that the direction of the movements in areas of upheaval or subsidence remains the same during long periods (see Clement Reid in *Nature*, 12 August, 1886), the probability is that in the course of ages, not greatly remote in a geological sense, there will be further changes of level in the south-west of England.

One of the most interesting observations made by Mr. Barrow in the Memoir just referred to is that there are in the granite of Great Ganilly fissures with an east-north-east and west-south-west trend, along which greisenization has taken place, these being altogether similar to what may be noted in the great granitic masses of the south-west of England, as, e.g., in the cliffs of Cligga Head and at Rock Hill, St. Austell. These fissures preceded in date another series trending slightly west of north, which were largely operative in effecting the present configuration of the islands, and, like the greisen bands, are well represented in Cornwall, though devoid of the iron and lead ores that characterize them in the latter locality.

It would be impossible within the limits of this Address even to allude to many of the important results already achieved in respect to Cornish geology by the officers of H.M. Geological Survey. I cannot, however, refrain from briefly referring to a few facts that seem to me of special interest. One of these is that the boundary between the granite mass of Bodmin Moor and the Devonian rocks is found to be not infrequently a fault. In the same district the peculiar flattened ellipsoidal form of the blocks constituting the tors has been shown by Mr. Barrow to be due to original structure and not to surface-weathering (*Mem. Geol. Survey, Summary of Progress*, 1907, p. 33).

The conclusions recently arrived at by Dr. Flett with regard to the structure of the Lizard are of peculiar interest. Its schists

evidence that they must have been folded and rolled out when intensely hot. The different members of the succession of rocks were folded actually at the time of their injection or shortly afterwards. Even after the intrusion of rocks had ceased, there were two distinct periods of enormous earth pressures; and it appears that the foliation of dikes and sills in the massive or nearly massive rocks is the effect partly of injection and partly of pressure.

The diversity of the structures in the Lizard complex Dr. Flett attributes to intermittent or spasmodic pressures acting on rock masses varying in condition from solid and nearly cold to hot and plastic (*Summary sup. cit.*, p. 27). I need scarcely add that the recent Memoirs issued by H.M. Geological Survey in illustration of the geology of Cornwall are so replete with important instruction that the publication of the volumes to complete the series must be eagerly looked forward to by all persons whose interests lie in the domain of rocks, minerals, and fossils.

As pointed out already in this and in my previous Address, for quite two hundred years the products of the mines and quarries of Cornwall have received the attention of writers, and the past few decades have shown no falling off in the supply of materials for instructive mineralogical memoirs. It was in 1858 that a vast amount of scattered detail was brought together in orderly fashion by Messrs. Greg and Lettsom in their yet frequently consulted manual of mineralogy, a work in which Cornish minerals, more particularly their sources and paragenesis, receive special notice. Subsequently our esteemed honorary member Mr. J. H. Collins, in his handbook on the mineralogy of Cornwall and Devon, made reference to many fresh additions to the list of Cornish minerals. The limits of so compendious a publication proved, however, to be inadequate for the record of the occurrence and for the description of yet more minerals new to Cornwall—some even new to science—that workers in well-known or quite fresh localities brought to light. An example of danalite finer than any yielded by American sources was discovered among

odd specimens collected by the late Mr. Talling. Monazite proved to be sparsely but well represented in the quartz veins of the Tintagel slates. Dr. Hutchinson's keen vision not long ago detected stokesite, a mineral of considerable chemical interest, on Roscommon Cliff axinite in the Carne Collection, acquired by the Cambridge Museum some years ago. More recently Professor Bowman, of Oxford, determined crystals from East Cornwall submitted to him by their discoverer, Mr. F. H. Butler, to be bertrandite, a hydrated silicate of beryllium. Shortly afterwards Mr. Arthur M. Russell came upon small crystals of phenacite, the anhydrous silicate, in the same and in yet another locality. I must not, however, attempt to indicate all the various advances made of late years in the department of Cornish mineralogy.

In some minds may arise the question whether the patient study and the record of the mode of occurrence and of the habit of comparatively rare minerals in a given district are of any particular importance in the province of applied science. A little consideration, however, with some insight into facts, soon leads to the conclusion that every correct geological and mineralogical record has its scientific import, though what precisely that may be should remain for long time unrevealed. But for the previous study of the at one time rare mineral monazite, it is doubtful whether the vast deposits containing that valuable source of zirconium would even by now have been exploited. Not infrequently has it happened that the discovery of some mineral of no economic worth has led the explorer to suspect the proximity of and to search for some paragenetic species of high importance. The finding, say, in a gossan of a single crystal of antunite might stimulate the prospector to a quest eventuating in the discovery of that most marketable uranium compound, pitchblende. A knowledge of the chemistry of minerals useless to the manufacturer has doubtless been a guide to the employment of the magnetic separator for their elimination from metallurgical material. One scientifically interesting result of research into the history and composition of minerals

that may be of no moment to the metal-broker is at times the establishment of the identity of Nature's operations in regions widely remote, although the development of a particular species in one locality may be insignificant in comparison with that in another. Any, though apparently the most trifling, geological or mineralogical observation may prove of profound significance to the intelligent pioneer in countries whose resources still require development. A uniformitarian not simply by precept, but by the force of patent facts, he travels in a strange land, looking always for that which he has seen and learnt to recognize at home; and the piece of schorl that he picks up by the Zambesi River reads him the same lesson as its counterpart to all appearance long since met with in St. Austell parish or in the wilds of Dartmoor. He knows by experience the truth of the old saying: "The thing that hath been, it is that which shall be; and that which is done is that which shall be done; and there is no new thing under the sun."

The importance of what half a century ago was doubtless regarded by the great majority of the public, and even by many persons feeling some degree of instinctive respect for scientific workers, as purely transcendental petrological research—mere philosophic peddling of no practical moment—was well exemplified in a recent legal dispute. Scientific professors and experts were summoned to the metropolis from distant cities, and invited to state their unbiassed convictions and opinions. The terms killas, growan, kaolin, kaolinite, china-clay, schorl, and many more that sounded passing strange to the good folk of London, became familiar in the mouths of counsel and witnesses as household words, for one of the questions at issue, the evidence on which alone must have involved an expense of hundreds of pounds, was whether the kaolin of commerce is a product of subaerial weathering, or of pneumatolysis proceeding from below upwards. The pedigree of china-clay was at stake. One chemical gentleman had persuaded himself, as a result of his inspection of Cornish clay-works, that the final operation in the manufacture of china-clay is the removal by washing from weathered felspar,

i.e. kaolin, of sufficient alkaline constituents to render blue the water in the settling-pits.

Now fifty years ago Sorby demonstrated that the vesicles in the quartz of the St. Austell granite indicate by the nature of their contents a pressure of some 32,000 feet of superincumbent strata. But as precisely similar vesicles occur abundantly in the secondary quartz of the more or less dekaolinized derivatives of the St. Austell granite, e.g. greisen, it is manifest that the original rock was not only solidified, but was also kaolinized and then dekaolinized under deposits so thick as to preclude all possibility of the access of surface waters. In other words, the formation of the china-clay of Cornwall is due to pneumatolysis at great depths from the surface.

On this matter Sorby's inferences from experiments, quite apart from ulterior testimony, leave no shadow of doubt. This point is brought forward by Mr. F. H. Butler in a paper dealing with sundry changes in west of England rocks, read last June before the Mineralogical Society, wherein the author further gives reasons for concluding that the kaolinization of granite was effected, as in the Cripple Creek district in America, by weak but hot solutions of carbon dioxide. In the interests of students of lode-formation and mineralogists generally, it is to be hoped that the prospects of the metal trade may continue to be sufficiently bright to allow of the continued working of the many old and new mines that have been opened up of late years in this county.

It is a subject for very special regret that at the silver mine at Perranuthnoe, which gave promise of rivalling another source of silver ore in this district, namely, West Wheal Darlington, operations should have been suspended for some time past. The following of the argentiferous lode in depth, in respect of the possibility of marked changes in the nature of the ore procurable therefrom, would have doubtless afforded information of the greatest interest to the mining and mineralogical world.

I have this afternoon merely touched on sundry topics, any one

of which might have provided material for a prolonged discourse. I have led you speedily from dish to dish in a banquet of such Cornish good things as it has been feasible for me to set before you. On which, if on any of them, you are to satisfy your individual scientific appetites, I must leave it for you to decide. If among my patient hearers there be some disposed to take exception to the discursiveness of my Address, I must take refuge in the wise words of the distinguished Keeper of the Mineralogical Department of the British Museum: "It seems to me that a presidential Address on a specific subject is out of place. However valuable the Address in itself, expressing, as it often does, the results of years of patient study, it might with greater propriety and with equal effect be brought forward by the author in his unofficial capacity" (*Min. Mag.*, 1889, Vol. VIII, p. 139).

REPORT OF THE COUNCIL

To the Annual General Meeting, November 10th, 1908.

In accordance with a suggestion which had been under consideration for some years, the last annual meeting of the Society was held at Camborne, but the Council do not consider that the advantage obtained was enough to justify any similar migration this year. But as the sole object of the Society is to encourage the study of Geology, the experiment can be repeated at any time if there appears reason to believe that such a step will be of service to students of the science.

The Council regret that the offer made by the Society of a substantial prize for the "most important original discovery in mineralogical or geological science communicated during the year" has not met a better response, but they propose to offer the prize or prizes again in the coming year on the same conditions, believing that they are thereby making the best use of the material in their hands to encourage original research in these studies.

The financial position of the Society is thoroughly satisfactory; the additions to the Library even more numerous than usual; some very interesting specimens have been given to the Museum.

The Council regret to record the deaths during the past year of—Rev. John Tonkin, of Treverven, who died on the 16th February. Mr. Tonkin had been a member of the Society since 1871, and had served on the Council since 1894. Mr. Thomas Clark, of Germoe, who died on the 16th April, was throughout his life a thorough student of practical geology. Beginning life under great educational disadvantages, he attained by patient

and conscientious work the recognition which his knowledge and character fully earned. He was elected an associate of this Society in 1899, and was awarded the William Bolitho Medal in 1901.

Lord St. Levan, who died on the 16th May, was a lifelong member; he was elected a Trustee of the Society in 1881 and continued to hold the position until his death. He was President for the two years 1890–1 and 1891–2 and, until prevented by failing health, was always a most regular attendant at the meetings, and showed the greatest interest in the Society and its welfare.

The late Major C. W. Parkyn, of Truro, who was for many years the Hon. Sec. of the Royal Institution of Cornwall, although not a member of this Society, was always a most regular visitor at the meetings. The announcement of his death on the 11th June was received with sincere regret by all the members.

Mr. T. J. Lean, of Marazion, who assisted his father in the publication of Lean's *Engine Record*, and afterwards continued the publication for many years, died on the 11th July.

In consequence of the death of Lord St. Levan, Mr. T. B. Bolitho is left as the sole surviving Trustee. The Council recommend that Mr. Howard Fox, of Falmouth, and Mr. A. K. Barnett, of Penzance, be elected Trustees of the Society jointly with Mr. Bolitho.

The Council have decided to award the William Bolitho Medal for 1908 to Mr. T. R. Polwhele, F.G.S. They feel confident that the choice will meet the cordial approval of the members, who will join in their sincere expression of regret that Mr. Polwhele's health prevents him from being present to receive it.

LIBRARIAN'S REPORT.

1908.

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—— Geographical Society.
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Tuscany. Societa di Scienzi Naturali.
United States. Geological Survey.
Upsala. Geological Institute.
Vienna. K. K. Geologischen Reichsanstalt.

Vienna. K. K. Naturhistorichsen Hofmuseums.
Victoria. Geological Survey.
Western Australia. Geological Survey.
Wisconsin. Geol. and Nat. Hist. Society.
——. Academy.
Yale University.
Yorkshire Geological Society.

[*From the Authors.*]

Geological Aspect of the Lodes of Cornwall. D. A. Macalister.
On Serpentine and certain Crystalline Rocks in S.W. England. T. G. Bonney, F.G.S.
Uranium in Cornwall and Scandinavia. F. J. Stephens, F.G.S.
Die Stephanoceras. E. Mascke.
Recent Foraminifera of Galway. F. W. Millett, F.R.M.S.
The Larder Lake District, Ontario. R. W. Brock.
The Origin of certain Cañonlike Valleys. F. W. Harmer, F.G.S.
The Pliocene Deposits of the East of England. ,,
The Great Eastern Glacier. ,,
The Influence of Winds on Climate. ,,
Excursion to Aldeburg. ,,
The Origin of Pillow Lava in Cornwall. C. Reid and H. Dewey.
Rock Remains in the English Channel. R. Hansford Worth.
The Geology of the English Channel. ,, ,,

[*Purchased.*]

Palæontographical Society. Vol. lviii.
London, Edinburgh, and Dublin Philosophical Magazine.

CURATOR'S REPORT.

DONATIONS TO THE MUSEUM.

THE DIRECTORS :—

Tin Stone from Wheal Kitty and Penhall.

MR. S. JAMES :—

Copper from Boscaswell, St. Just.

MR. J. HARRY :—

Native Copper from Mullion.

MR. J. T. RODDA :—

Casts of Felspar Crystals.

MR. T. C. PARIS :—

Portrait of Dr. J. A. Paris.

[*Purchased.*]

Mundic from Gwavas Quarry, Newlyn.

Quartz Crystal, Levant Mine, St. Just.

STATEMENT OF RECEIPTS AND EXPENDITURE FOR THE YEAR 1907–8.

Dr. *The Treasurer in Account with the Royal Geological Society of Cornwall.* **Cr.**

Receipts.

November 10th, 1908—	£	s.	d.	£	s.	d.
To Balance from 1907				36	8	1
,, Ordinary Subscriptions and Arrears	37	16	0			
,, Subscription per His Royal Highness the Prince of Wales . . .	20	0	0			
,, One Year's Dividend on £1800 Midland Railway 2½ % Debenture Stock, £45, less tax £2 5s. . .	42	15	0			
,, Sale of *Transactions* . . .	0	5	0			
				100	16	0
				£137	4	1
November 10th, 1908—						
To Balance in Treasurer's hands				£51	1	10

Expenditure.

November 10th, 1908—	£	s.	d.	£	s.	d.
By Rates and Taxes	0	8	0			
,, Curator's Salary	42	15	0			
,, *Transactions*, Periodicals, Printing, and Stationery	17	6	7			
,, Fire Insurance Premium . .	2	12	9			
,, Coals and Gas	11	6	11			
,, Sundry Repairs to Buildings . .	7	11	9			
,, Postages and Petty Disbursements .	4	1	3			
				86	2	3
,, Balance				51	1	10
				£137	4	1

T. R. BOLITHO, *per pro, Treasurer.*

LIST OF PAPERS

READ TO AND PUBLISHED BY THE SOCIETY.

1908.

President's Address. A. K. Barnett, F.G.S.

On the Geological Structure of Western Cornwall. Upfield Green, F.G.S.

On a Polished Block of Quartzite in the Meneage Peninsula. W. Rogers.

On a Fossil Tree at Porthmeor, St. Eval. C. G. Lamb.

A New Deep Well at Sheffield, Paul. T. Maddern.

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ON THE GEOLOGICAL STRUCTURE OF WESTERN CORNWALL.

By Upfield Green, F.G.S.

In the present paper an attempt is made to treat in some detail of the tectonics of the neighbourhood of Truro as affected by the great post-carboniferous earth-movements known as the Hercynian torsion folds. It is not from any desire to criticize or minimize the work of the Geological Survey that I take as the basis of my paper the maps they have lately issued. On the contrary, I desire to bear testimony to the care with which most of the mapping has been done on the six-inch maps, and these have afforded me much information as well as unexpected corroboration of my views. The Survey have confined themselves principally (in the absence of fossil remains) to mapping various petrologically similar districts, and have refrained from illustrating by suitable sections or descriptions the tectonics of the country. It is therefore almost impossible, from the published one-inch maps and the accompanying Memoirs, to form any conception of the structure of the country or of the sequence of the formations. The Survey itself is unable to account

for the sequence of their Veryan, Porthscatho, Falmouth, and Mylor beds, beyond intimating as a final conclusion that possibly the Mylor beds may be the centre of an anticlinal, followed on the east by Falmouth and Porthscatho beds, to which succeed the Veryan (thus making the latter the youngest beds of their series), followed by, or being itself, the "Ordovician" (see p. 7).

In this paper I deal with only a small portion of the Hercynian synclinorium comprised between the anticlines formerly existing in the Bristol and English Channels ([1, 2, 3, 4]).* Both these are, as is so frequently the case, more or less denuded, but the evidence of their former existence is undoubted. Included in this synclinorium are the Gedinnian, the three divisions of the fossiliferous Devonian, and the Culm. Only the Gedinnian and the lower Devonian comprised between Watergate Bay and Veryan Bay will be here discussed.

In any attempt to unravel the structure of an apparently unfossiliferous country the nature of its relations to adjoining fossiliferous areas will naturally be the first consideration. The possible extension of known, recognizable beds, the existence of petrologically comparable rocks, and last, though not least, the surmises of previous writers, will also engage our attention. As Beete Jukes says, "Nothing short of a thoroughly exhaustive survey of the whole country, under the guidance of a clue derived from some other country where the same

* Figures in brackets ( ) allude to References, page 296.

rocks lie more nearly in their natural order and original positions will suffice."*

As regards the first question, viz. the adjoining fossiliferous districts, we have, fortunately, on the north and east, rocks easily recognizable as Dartmouth slates, while on the south there is a fringe of rocks, the age of which is acknowledged to be older than these slates. In these older rocks various fossils have been found from time to time which have been assigned to ages varying from the Ordovician to the Upper Silurian. To these rocks, which form the north or tilt slope of the overfold of a grand anticlinal ([1, 3, 4]), we will first devote our attention. They commence somewhat to the east of Gorran, consisting there principally of quartzitic rocks in which badly preserved fossils sporadically occur. These quartzites, with associated slates, emerge and are traceable at intervals through brecciated conglomeratic rocks. To the whole of these the name of Veryan has been applied by the Survey, and in them have been intruded various igneous rocks.

This eastern and most continuously exposed of the quartzitic groups may be best studied at Porthluney Cove, near Caerhays. It projects as Diamond Point. Both here and on the north-easterly extension of the strike at Great Carn (Gorran) fossils have been found apparently *in situ*. They occur both in a calcareous and a quartzitic matrix. The

* J. Beete Jukes, 1868, *R. Geol. S. of Ireland*, XII, November 13th, 1867, p. 85.

south-westerly extension of this strike extends seawards, and is lost to view. A similar parallel occurrence of conglomeratic and quartzitic rocks is traceable from west of Portholland, through Portlooe and Caracloose, running out to sea at Carn (Veryan), where also fossils in both quartzite and limestone have been found. A third parallel band, in which, however, no traces of the quartzitic rocks have been detected, crops out somewhat west of Porthmellon and at Trevarrick, appearing again at Polgrain, whence, according to the Survey, it is traceable over the heights south of Tippet's shop to Calendra and Veryan, where it merges in the last-mentioned band and continues with this to Pendower, there disappearing seawards.*

Between and partly overlying these three parallel bands of rock are unconformable deposits of coarse to fine grained grits, which the Survey have assigned to "Lower Devonian sandstone." I myself consider these as the lowest of the Survey's Porthscatho beds (my Mylor-Veryan, *infra*) occurring in short synclinals between Silurian anticlinals, or possibly ridges.

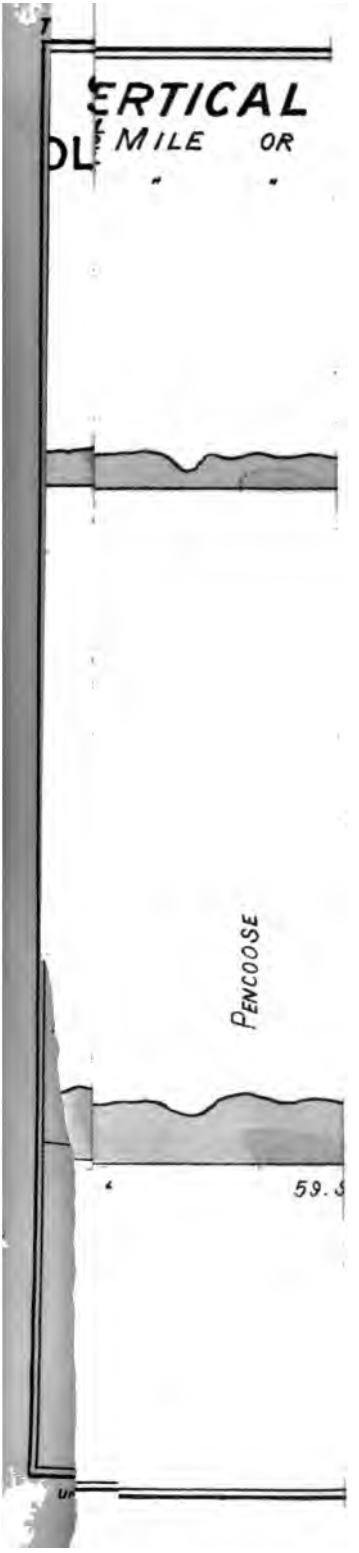
Approximately parallel to these anticlinal curving folds of older rocks follows another curving anticlinal, the exposed arm (overfold) of which is terminated by Falmouth beds, traceable north-easterly from the Camborne granite through Truro

* A similarly arranged series of rocks, with a similar strike, was detected by De la Beche south of the Helford river, but this occurrence may, for the present at least, be neglected.

to St. Erme, and thence south-easterly through St. Allen to Summercourt, near St. Enoder and St. Austell. The enclosed synclinal is occupied by Porthscatho and Falmouth beds. These Porthscatho beds are traced by the Survey on their southern border from Veryan on the west to Treberrick on the east, where their outcrop is apparently supposed to terminate and pass under the beds termed "Lower Devonian sandstones." I consider these to be the continuation of the Porthscatho overlying the Mylor-Veryan and merging into the before-mentioned short synclinals to the coast.

Further north another anticlinal, with its axis dipping east, occurs; the synclinal between this and the last-mentioned anticline being occupied by Meadfoot (possibly also Staddon) beds and terminating in its northern limb and anticlinal with the fossiliferous Dartmouth slate at Watergate Bay, with possibly inlying Porthscatho. This anticlinal is termed by the Survey the key to the structure of Cornwall. In my opinion it is but a ward of the key, the true key being the southern Silurian anticlinal.

Such are the results of my own observations, biassed, it may be, and I am not ashamed to acknowledge it, by those recorded by such geologists as Sedgwick and Murchison, De la Beche, Beete Jukes, Godwin-Austen, Ussher, Hudleston, and other English authors; Suess, Heim, Barrois, Gosselet, Moissenet, Lohest, Forir, Koch, Kayser,


ERTICAL
MILE OR
PENCOOSE
59.

Lossen, Rothpletz, Frech, and many other foreign observers.

I have taken as my guide John Dalton's method of procedure as referred to by Roscoe in his Presidential Address to the British Association in 1887: "The assumption of a certain view as a working hypothesis and the subsequent institution of experiment to bring this hypothesis to a test of reality." *

A Survey officer once remarked to me that sectionizing was a dangerous proceeding. I have the courage of my convictions, and in accordance with the observations described above have indicated on the accompanying map the three principal anticlinals and on the corresponding section details of the included synclinals. I, myself, prefer including the Porthscatho and the Falmouth beds under the continental name of Gedinnian, but as Mr. Hill has mapped them in great detail I have retained his names to avoid confusion. You will notice that mine is not a detailed map, but a diagrammatic and tectonic one. It is naturally the result of a survey by myself. It differs much in its tectonics, but little in its mapping, from that of the Geological Survey, as you will perceive by comparing the two maps. This difference is to be accounted for partly by the initial divergence of opinion as to the age and sequence of the beds and partly by non-recognition by the Survey of Inversion of Anticlinals, which is so characteristic of Hercynian folding, and

* *Report Brit. Assoc.*, 1887 (1888), p. 7.

by the confusing of the tilt slope of the overfold of "Silurian, etc.," with overthrust.

The two opinions as to the sequence are as follows:—

Survey Sequence.§

Staddon	Lower Devonian.
Meadfoot	
Old Red	
Dartmouth	
Ladock	
Manaccan	

lying unconformably on

*Veryan (probably Arenig).	
*Portscatho	Earlier Palaeozoics.
*Falmouth	
*Mylor (oldest and centre of anticline).	

All of which may be base of Ordovician or top of Cambrian.

* "With difficulty distinguishable from one another."

Proposed Sequence.

Staddon	=	Coblenzian.
Meadfoot	=	Taunusian.
†Dartmouth		Upper Gedinnian
Falmouth		
‖Porthscatho.	Middle	,,
°Mylor-Veryan.	Lower	,,

lying unconformably on

Slates with inclusions, Quartzites, Igneous rocks, etc., which, till differentiated, may be denominated "Silurian, etc." These are also affected by the Hercynian movement ([5, 6, 7, 8]).

†Fine argillaceous and sandy beds, weathering ashy grey, tender, and frequently unctuous and glossy. When disturbed by tilting and twining, prone to decomposition into silty beds (Perran shales of the Survey).

‖ Alternating fine grits and sandy bluish slates, weathering buff, frequently micaceous. At places, beds of the matrix mentioned below

joining on to

° Coarse grits and conglomerates generally more or less calcareous and felspathic, with large and small lenticles of quartzite and Silurian slates. In the neighbourhood of igneous intrusions ([13]) they contain a great variety of apparently much older rocks cemented by a matrix of coarse grit resembling tuff, and described as such by De la Beche, Fox, and others.

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§ "Ludlow, Wenlock, Gorren Haven and Veryan Beds, Portscatho, Falmouth, Mylor, Dodman series," *Summary Progress Geol. Survey for 1905*, p. 25, of which the Gorran and lower beds are referred to Lower Silurian and possibly Cambrian or older.

In the *Summary of Progress for 1906* the Veryan is said to be of Arenig age; the sequence "is descending from the Veryan to the

I also infer, though it is not definitely expressed in the Memoirs, that the Survey considers the "Manaccan Series" to have extended continuously over the asserted "Earlier Palaeozoics" to the "Ladock beds," and to have been removed by denudation.

I regard the *conglomerate* of the Veryan beds of the Survey as corresponding to the Mylor, but containing coarser material at places.

To justify my opinion as to the sequence of the beds, I will invite you to make a traverse with me across the strike from Trerathick Point, north of Watergate Bay, to Veryan Bay, and attempt to construct a diagrammatic section ([9]). It will not take us long on paper.

At Trerathick Point (north of Watergate Bay) we find Staddon Grits (=Coblenzian); about one mile east of Mawgan Porth, near Porth Farm, we meet with the Meadfoot beds (=Taunusian); just west of St. Mawgan, near Trevarrian, we encounter beds which, both from their petrological appearance, coloration, and contained fish-remains, are easily re-

Mylor," and these lower deposits may represent the base of the Ordovician or top of the Cambrian (p. 30).

In the *Summary of Progress for 1907*, p. 28, the succession is given at "Porthscatho, Mylor, Falmouth and Veryan," and these beds are referred to as "Ordovician with possibly some Cambrian rocks."

In A. Macalister (*Economic Geology*, Vol. III, No. 5, 1908, pp. 363–6) these rocks are referred to as Cambrian, and a map is given, by permission of the Director of the Geological Survey, in which the whole mass south of North of Truro is hatched and described definitely as Cambrian, thus subverting the opinion expressed on the one-inch maps so recently issued to the public, as well as the various opinions quoted above as expressed in the *Summaries of Progress.*

cognized as a prolongation of the Dartmouth beds of Ussher (my Upper Gedinnian), which he has with infinite pains traced from Scabbacombe Head, near Dartmouth, on the east, to Fowey and Lanreath on the west. We know from Ussher's mapping and description that these are inverted over Meadfoot fossiliferous beds, and are therefore the north tilt slope of an anticlinical strike dip (overfold). The deeper underlying beds have not been detected eastwards owing to the dip strike. It is not difficult to see that the beds here are, as generally in Cornwall, inverted, and that they constitute an anticlinal with a very much broken tilt slope on the north and a less inclined dip slope to the south. The dip, or uninverted slope, is naturally the indication of the upper portion of the beds. The cleavage cuts through the dip and tilt slopes at different angles, and is responsible for the greater deformation of the fossils in the latter.

Resting on the dip slope of these beds, therefore, to the south near Parkyn's shop are younger (Meadfoot = Taunusian) beds, and it is not till we reach the neighbourhood of Mitchell that we find rocks which, to any one acquainted with the Falmouth and Dartmouth beds, suspiciously resemble these as noticed at Watergate Bay,

In this case we have encountered the tilt slope of these beds (Falmouth = Upper Gedinnian, repeated), and, continuing south till about one mile north of Grampound Road, we come upon a succession of sandy slates and fine grits, being the denuded tilt

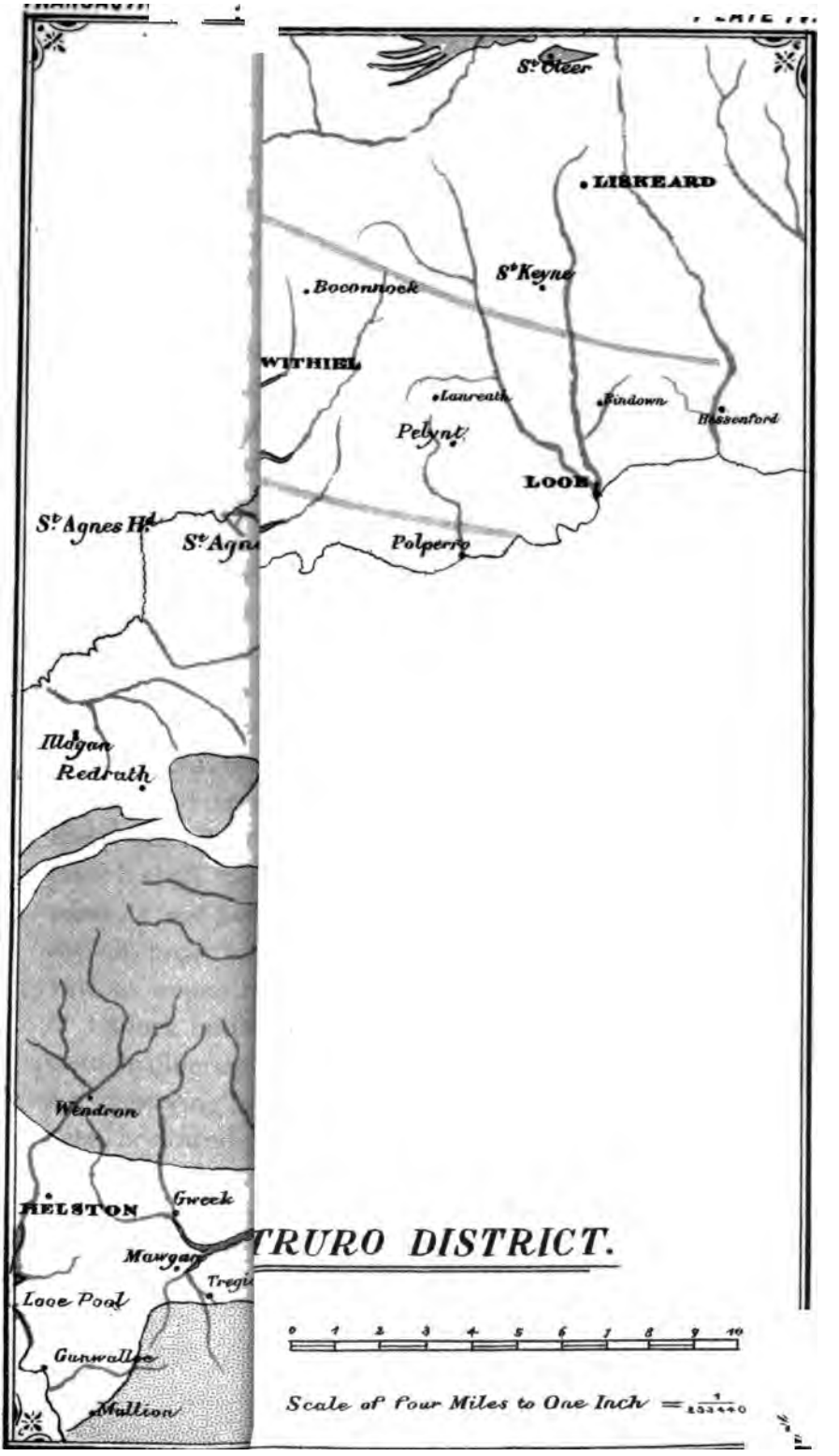
slope of a new member of the series and termed Porthscatho (=my Middle Gedinnian). These beds continue till Grampound Road is reached, where the tilt slope of the Mylor-Veryan (my Lower Gedinnian) emerges. At a slight distance south of the railway line the dip slope of the Mylor runs under the Porthscatho, its tilt slope emerging again near the Fal river. The beds are well exposed in Halebote quarries, the northern quarry showing the tilt slope and the southern quarry the dip slope. Just south of the southern quarry the Mylor beds again disappear, to be succeeded by a synclinal, anticlinal and synclinal of the Porthscatho beds. About half a mile north of Polgrain we see the Igneous, Silurian, and Ordovician rocks previously mentioned.

Having now investigated the vertical structure and the sequence of the beds on this section, we will turn our attention to what may be called the "Guide lines" of the structure, namely, its latitudinal and horizontal extension.

First Guide Line.—Commencing with the south line (in my opinion the key to the structure), we find the northern face of an arc of pre-Devonian rocks, as mapped by De la Beche and the Survey, being the inverted or tilt slope of an anticlinal overfold of these rocks, the southern dip slope of which must have extended into the Channel. The apex of this fold has been denuded. On the northern side of these rocks, and participating with them in the Hercynian folding, were deposited what I consider the Gedinnian beds. Assuming this surmise

to be correct, we have, therefore, to seek the older rocks on the south side in the preserved portion from Gorran to Pendower; on the east in the entirely denuded portion from Pendower through Old Wall to Nare Point, Helford river; and again, on the south, in the preserved portion extending from Nare Point through Tregidden. There they are covered by Serpentine either overthrust or flow, and, emerging near Cury on the west, again assume a southerly direction,

SECOND GUIDE LINE.—Succeeding this anticlinal and approximately parallel to it (*omitting all minor folds*) is a major anticlinal, the apex of the lowest beds of which (the Mylor-Veryan conglomerate) is exposed at Grampound Road, the overlying beds of the Porthscatho and Falmouth having been at this point denuded. The "Guide line" of this anticlinal extends thence in a generally south-east direction to St. Austell, the conglomerate being exposed at various points in the beds of the streams running north and south, while the south-westerly extension may be traced to Lanner, north of Truro, where the changed strike and dip may be observed. These beds are tilted and here disappear, not being seen again till they emerge from beneath the fish-beds of Lynmouth on the Bristol Channel. The partially denuded dip slope of the Falmouth and Porthscatho beds may be followed in a south-westerly direction to Truro ([10]) and the "Guide line" continued north of St. Austell to Fowey, Polperro, south of Looe, and Portwrinkle.


St. Cleer
LISKEARD
St. Keyne
Boconnoock
WITHIEL
Lanreath
Pelynt
Findown
Hessenford
LOOE
St. Agnes Hd.
St. Agn
Polperro
Illogan
Redruth
Wendron
HELSTON
Gweek
Mawgan
Tregi
Looe Pool
Gunwalloe
Mullion
TRURO DISTRICT.
0 1 2 3 4 5 6 7 8 9 10
Scale of Four Miles to One Inch = 1/253440

THIRD GUIDE LINE. — Another approximately parallel anticline is found on the north coast at Watergate Bay, extending south-west by St. Agnes and south-east to Lanreath, Bindown and Hessenford.

It cannot, of course, be expected that the mapping will exactly conform to these lines, as they have been modified by varying horizontal dip of axis ([11, 12]) by surface denudation, by cross faults and greater or less overthrust owing to varying pressure or resistance.

I have now described as briefly as possible in outline what I believe to be the true structure of this part of Cornwall. The *details*, deduced from my own observations and study of previous authors (a few references to whom I append), I must regretfully leave to future observers with more time, health, and strength than I now possess. I have spent the leisure of fifteen years upon the problem, and I shall be pleased, later on, to communicate some of my numerous notes to fellow students. I, myself, hope to be able to deal more fully with the various exposures of the Mylor-Veryan, Manaccan or Ladock beds, and give more detailed description of their different peculiarities, which, in my opinion, are deserving of much greater attention than has been bestowed upon them in the Memoirs of the Geological Survey.

I cannot conclude without acknowledgment of assistance, geological, physical and social, rendered me by my friends H. Vassal, F.G.S., and C. Davies

Sherborn, F.G.S. Indeed, but for the persistent representations by the latter of my obligations to your Society, I am afraid this paper would never have been written. I am, as a Belgian friend once observed, more a "travailleur" than a "litterateur."

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10. SCRIVENOR, 1902, *Report of Progress Geol. Survey*, p. 26, and Six-inch Map, 49 S.W.

11. REID, etc., 1906, *Mem. Geol. Survey, Newquay.*

12. BARROIS, 1894, *Ann. de la Soc. Géol. du Nord*, XXII, p. 331.

13. GEIKIE, 1891, *Ann. Address Geol. Society*, pp. 124, 125.

I would also draw attention to Professor Barrois' explanation of the "Plougerneau" Sheet of the *Geol. Survey of France*, *Ann. de la Soc. Géol. du Nord*, Vol. XXI, p. 382, and foot-note, p. 390.

NOTE ON A POLISHED BLOCK OF QUARTZITE IN THE MENEAGE PENINSULA.

By W. Rogers.

Near the head of the valley leading down to Gillan Cove in the parish of St. Anthony in Meneage, there are two farms—Tregasso and Trewarnevas. In a field between these two there is a large block of light-grey quartzite, which attracts attention by its extremely polished face. Many of the blocks in this district have rounded corners, and even seem to be smoothed and worn; but this one is highly polished on two faces, which form a square corner pointing about N.E. The other sides of the block are irregular; the greatest diameter is about 20 ft., height of face 8 ft. The flattish top slopes backwards to the level of the rising bank; it is partly covered with turf, in which are embedded angular fragments of quartzite. Standing on the block, one looks down the valley N.N.E. over Dennis Head and Rosemullion Head to Falmouth. In front are two other blocks, one about one-third of the size, the other much

smaller. Thinking that cattle might have polished it, I obtained a small piece from a quartzite rubbing-post, but that is only polished at a few projecting corners, whereas the block in question is polished over a large and undulating surface. It is unreasonable to suppose that a Cornish farmer should have taken the trouble to polish so large a surface. The absence of striae seems to preclude the action of ice. But it is difficult to see what else can have produced such a polish.

Wave action or blown sand have been suggested.

The distribution of these blocks of quartzite in the district seems peculiar, and calls for explanation. A great many of them have been destroyed since Mr. J. H. Collins observed them nearly thirty years ago; and the lines of outcrop which he traced are now scarcely recognizable. But it seems doubtful whether they are generally found *in situ.* They usually occur as flattish masses lying on the clay—what they call the "wet lands"—and they are not quarried anywhere. The question is how they got there and when. No doubt the Geological Survey will have something to say on this point.

NOTE ON THE OCCURRENCE OF A FOSSIL TREE AT PORTHMEOR, ST. EVAL.

C. G. LAMB, M.A., B.Sc., Clare College, Cambridge.

Communicated by HOWARD FOX.

(Read November 10th, 1908).

THE small inlet of Porthmeor, in the parish of St. Eval, differs from most others on that part of the Cornish coast in the nature of the foreshore. It is nearly devoid of sand, but is covered with a shingle formed principally of water-worn slate, the material varying in size from that of ordinary small shingle to fairly large stones several inches in diameter. This peculiarity is probably due to the shielding effect of Trescore islands and other outlying rocks. Such a shingle is much less readily removed by tidal action than is a sandy beach. From this it results that the amplitude of variation of the level of the foreshore is far less than is the case with the neighbouring sandy inlets.

In the first week of this September (1908) there was an exceptional diminution in the amount of overlying shingle, which was in places completely

removed; below it was exposed a bed of stiff clay, the area of which was, however, only a few square yards. In the clay was embedded the stump of a tree; from the size, extent, and distribution of the roots it was evident that the stump was *in situ.* The general facies and the nature of the bark were those of a conifer. In addition to the presence of the stump there were small portions of decomposed wood embedded in the clay.

The subsequent October tides brought back the shingle, and the place is now again covered up by the same.

A NEW DEEP WELL.

By T. Maddern.

It may be interesting to the Geological Society to have the following data *re* the cores taken from the new deep well at Sheffield, Paul, sunk for Messrs. R. R. Bath and Newlyn Ice Co. by Messrs. Duke and Ockenden, well-sinkers, Southwark Street, London.

As the sinking was only finished last week I have not been able to give you the particulars before.

The Ice Co., being anxious to secure a water supply free from all contamination, instructed me to arrange with the above firm to sink a deep bore hole on the site and supervise the work.

We anticipated striking granite at 11 ft. or 12 ft. from the surface, and found it at 10 ft., under a layer of meat earth and marl.

The first layers were the usual thin brown strata found in most of the top beds of the local quarries. At a depth of 20 ft. from the surface we cut in the centre of the core a vertical vein of quartz, which supplied enough water to overflow the top lining-pipe which acts as a guide to the boring-bit and is

driven from the surface into the granite; it also keeps out all surface water.

This vein split the core for about 30 ft. continuously.

A softer water-bearing granite was then entered, which refused to give a good core and filled the sediment tube repeatedly. The depth of this bed was about 15 ft., with slight traces of a lode, this was followed by a seam of hard granite similar to the Lamorna quarry; this bed is practically dry. After cutting through it, a second vertical vein of quartz was cut, and in this piece of core you can see the hard granite on one side and the soft on the other, with traces of another lode. It terminates in a three-sided vertical joint much waterworn on one side. From this we sank through a continuation of soft granite until the hard was again reached, when the boring was stopped and a thirty-five hours' pumping test was run. The yield was 2000 gals. at 6 ft. water rest, 3000 gals. at 8 ft. 6 in., and 4000 gals. at 12 ft. 6 in., where it remained during thirty hours. The diameter of the boring-bit (which is a mild steel hollow cylinder) is $7\frac{3}{4}$ in., cutting an 8 in. hole.

The cylinder is rotated by means of suitable machinery, and is suspended by hollow steel rods, through which is pumped a constant stream of water. The lower edge of the boring-tube is cut with four hollows, similar to saw teeth, for the egress of the water, and also to allow the cold steel shot to rotate easily.

The cutting is really performed by the shot, of which we used one hundredweight in cutting 90 ft., although at the same time the boring-tube was worn two feet shorter than when it commenced.

In the large photo you will see the boring-tube with the sediment-tube attached suspended from the derrick. The sediment-tube is fitted with valves to allow the inflow of water to wash the grit as it is cut up into it; but on stopping the pumping, the valves shut, and all the grit is then held above the boring-tube.

The other photo shows a general view of the derrick and plant. I have also pleasure in sending you with this the last cutting taken from the chalybite spring in the works, which comes from 180 ft. from the surface, but as the boring was performed by concussion there was no core.

Royal Geological Society of Cornwall.

THE NINETY-SIXTH

ANNUAL REPORT

ETC.

PENZANCE.

1910.

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The Secretary requests the favour of his being informed of any inaccuracies in the foregoing lists.

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1909–1910.	W. COLENSO, ESQ.

Photo: Gibson & Son, Penzance

SUBMERGED FOREST, MOUNT'S BAY. NO. 1

To precede page 313

Photo: Gibson & Son, Penzance

SUBMERGED FOREST, MOUNT'S BAY. ROOT OF LARGE TREE. NO. 2

Photo: Gibson & Son, Penzance

SUBMERGED FOREST, MOUNT'S BAY. NO. 3

Photo: Gibson & Son, Penzance

SUBMERGED FOREST, MOUNT'S BAY. NO. 4

Photo: Gibson & Son, Penzance

SUBMERGED FOREST, MOUNT'S BAY. NO. 5

Photo: Gibson & Son, Penzance

SUBMERGED FOREST, MOUNT'S BAY. ROOT OF LARGE TREE. NO. 6

Photo: Gibson & Son, Penzance

SUBMERGED FOREST, MOUNT'S BAY. LARGE TREE BELOW LAREGAN. NO. 7

Photo: Gibson & Son, Penzance

SUBMERGED FOREST, MOUNT'S BAY. ROOT OF LARGE TREE. NO. 6

Photo: Gibson & Son, Penzance

SUBMERGED FOREST, MOUNT'S BAY. LARGE TREE BELOW LAREGAN. NO. 7

THE

ANNIVERSARY ADDRESS OF THE PRESIDENT,

WILLIAM COLENSO, Esq.,

To the General Meeting, November 10th, 1909.

Ladies and Gentlemen,—I feel it a great honour to be here to-day as your President. To have been chosen to succeed so eminent a series of gentlemen in the occupancy of this chair is highly gratifying to me. I have interested myself in the subject of Submerged Forests and Raised Beaches, and hope that the paper I now propose to read will prove worthy of your attention.

The submerged forests of Mount's Bay belong to the Neolithic period,* probably at least three thousand years ago, and although the subject of submerged forests and raised beaches has on several occasions been noticed by such eminent men as Borlase, Carne, Boase, Ussher, and others, it is still worthy of attention.

It is my intention to use photographs to in some way illustrate my remarks.

In the first place I would call your attention to Borlase's *Natural History of Cornwall*, page 220.† "In the year 1740, Christopher Hawkins, Esq,, of Trewinard, draining a marshy piece of ground on the banks of the river Hayle, in Penwith, found several pieces of oak, buried four feet deep or more under the surface, in a fast clay, one large stock of a tree about ten

* *The Geology of the Land's End District*, 1907, page 4.

† Folio, Oxford, 1758.

feet long had no branches, its top part pointing down hill, the colour of it very black. The timber was hard and firm." "In the year 1750, John Roberts in the parish of Sennen, digging for tin near Velindreath, found, at the depth of thirty feet, an entire skeleton, about the bigness of that of a large deer, but such a set of bones as he had never before observed. The beast lay on its side, and near it, in line parallel to its vertebræ, a prostrate tree of twenty feet long, about the diameter of a moderate man's waist: great numbers of leaves were on the branches, some large, some small, and the impression of the leaves was plain in the earth. The tree was of the oak kind, and so soft in some parts that the shovel stuck in it, but extremely hard at the knots and spurs; not far from the skeleton, but unconnected, lay part of a deer's horn two feet and a half long, thicker than a man's arm wrist, with the branched antlers to it; one of the knobs was as big as a man's fist. In 1753 other pieces of deer's or elk's horn were found in the same place twenty feet below the surface." Mr. Borlase also explains on page 222 the Mount's Bay submerged forest as it appeared on the 10th of January, 1757, after the sand had been removed by a violent sea between the piers of St. Michael's Mount and Penzance.

I think the accompanying photographs, taken in 1883, one hundred and twenty six years later, wonderfully illustrate and corroborate Mr. Borlase's observations, although in the latter instance more of the sand had been taken out to sea.

Photos Nos. 1, 2, and 3 are taken from the sands looking towards the Mount, and show almost individual specimens of trees, while No. 4, taken from farther east, gives a very good idea of the denudation of the vegetable matter. Nos. 5 and 6 are looking towards the Great Western Railway wall. No. 6 is a very good specimen of a large root. No. 7 shows the general appearance near Laregan with a large tree in the foreground, which tree has apparently fallen away from the shore. Near this spot several trees were quite uncovered; they were oak, very dark in colour—which might very well be termed black both inside and out.

I herewith present a small piece, which is very hard and durable. In 1883, the time when this sample was obtained, several pieces were sawn from the remains, and out of them various forms of mementos were made. The wood, from its great age, is rather brittle, and therefore might very well be called fossilised.

There seems to be some difference of opinion as to the period of the lowering of the land, in which those trees had grown and flourished for a long time. In counting the number of years it appears to be a comparatively short period, compared with the age of the earth. It seems that the oak found at Sennen and the forest in Mount's Bay are of the same period, and that in each place those trees grew some distance from the sea, or that our climate has considerably changed, and become much colder, as at the present time trees will not grow so prolificly anywhere near the sea in these districts; and although the ancient tradition may be quite right in saying that the St. Michael's Mount was situated in a wood, therefore it might very well have been called the "Hoare Rock" in the wood, even more than three thousand years ago. According to Sir Norman Lockyer's statement, some of our stone circles were erected at least fifteen hundred years B.C., and were at that time used for scientific purposes, thus showing that Cornwall was not only inhabited, but that the inhabitants were civilized at that time. It seems from the general appearance of the manner in which this forest has been preserved, that there must have been a sudden convulsion of the earth's crust. And I quite agree that the time was autumn, as both nuts and foliage go to prove this, as well as the leaves on the oak tree found at Sennen, which were large and small, showing the larger leaves as grown on the older wood with the rising of the sap, the smaller leaves would be those produced at the end of the summer on the new growth.

It is still a problem as to whether the sea or the sand came first, or whether the sand came with the sea. If the sea had been first, it seems that the whole of the vegetable matter would have been more broken and distributed. That the sand was

brought in great plenty in a very short time, either by the sea, or the winds, or both, seems very probable, both on the northern shore of Mount's Bay and at Sennen. However, the oak has been found more recently. In September of this year the accompanying piece was taken out of an old peat bed in Ludgvan, on the north, and not far from Castle-an-Dinas. This peat was cut into while removing the overburden from Mr. W. K. Baker's china clay; the peat was about six feet in depth and there was a good deal of it. Although the peat is full of fibre there are no signs of leaves; the wood was just as soft as the peat when removed, and as may be observed in the piece before you, it became hard on being exposed to the air, and dried. You may also observe the large quantity of fibre which has penetrated this sample in all directions. It was buried in the peat about five feet, and the china clay was only about four feet below the peat.

I will now say a few words about one or two raised beaches. Of course it is a generally known fact that raised beaches are observed at different places along the south coast from Brighton to South Wales, and usually not more than fifteen feet above the present sea level. This is the average height as given by Mr. Ussher in his valuable paper, which is in our library, and which will give valuable information to any member who may be interested; but since his time of writing, viz. 1879, another raised beach has been found in Penlee Quarry. Mr. Clement Reid in the *Geology of the Land's End District*, 1907, says, "The earliest Pleistocene* deposit preserved is the raised beach, which occurs in every sheltered bay or nook of the coast, at heights varying from the present sea level up to sixty-five feet above mean tide." Penlee Quarry exhibits one of the most important sections of these old marine deposits to be met with in West Cornwall. The quarry has cut through the shelf of the old cliff, and in one corner, between it and the road, the ancient beach is seen to rest on a water-worn platform at a height of sixty-five feet above Ordnance datum. The beach consists of well-rounded boulders, often as large as a man's head, and is

* Page 75.

mainly of local origin; above it is a mass of head and rain wash, from the hill above.

The raised beach found in the Morrab Road, Penzance, is about the same height as that in Penlee Quarry; the boulders of this beach seem to be of the same description of stone. I present herewith some specimens from Penlee Quarry, which show much weathering, and one piece is from a boulder which lay in three parts, some distance from each other, and it was found that by placing them together they formed one complete stone. Looking at the part which I have rubbed to a smooth surface, you will see that it contains fractures, and therefore would in time give angular pieces, and would in turn be mixed with the soil and become head. I mention this to show that what is known as head generally, in which so many angular stones are met with, might be formed in the same manner, viz. by weathering. These stones look very much like greenstone. The other raised beach is at Prah Sands. Here it is only a few feet above the sea, in the western part of the sands, and runs down towards the sea in an easterly direction and is lost in the sand. This beach has various kinds of stones fixed in a cement of sand and probably iron; these pebbles are of slate, quartz, and elvan; the slate is very much twisted, and as it is here very near the igneous rock might account for such disfiguration; here also some large blocks of slate are tilted, and at the present time are acting as supports carrying a great weight.

Now in looking at the raised beaches, if we consider the period of the raising, the earth's crust must have undergone such a change that the land all along our southern shore must have been very much more extensive than at present. The submerged forests prove this, but that is not all; the question might be asked, was there also a chalk formation south of Penzance? The pebbles now found on the shore of Mount's Bay contain a very large number of flints, there are also many flints to be found on the northern slopes of the bay embedded in clay, and those found in the clay, in weathering, show the colour of the clay outwardly, but when cut they have the appearance of

ordinary flints. I have here one from the beach at Penzance, cut and polished.

LADIES AND GENTLEMEN,—On behalf of this Society I present the "William Bolitho" Gold Medal to the Rev. D. G. Whitley. Mr. Whitley, it gives me much pleasure in presenting this medal to you. It marks the very high esteem and appreciation in which the Council regard your researches, and with them I hope you will continue to persevere in your geological studies of Cornwall, and so add to the knowledge of our Society.

REPORT OF THE COUNCIL

To the Annual General Meeting, November 10th, 1909.

THE Council are pleased to be able to report that the Museum, Library, and the buildings of the Society are in good condition. The several specimens added to the collection during the year are laid on the table. An essential addition to the bookshelf accommodation in the library has been made during the year, but the continued rapid increase of the books and pamphlets will make it necessary that further space should be provided. In March last, Mrs. Tupper, of Boskenwyn, kindly gave the Society two cases of drawers, which have been temporarily used for storing the specimens from Tasmania, which were sent to the Society from the Franco-British Exhibition in 1908. In April the Council received an application from the County Committee which was appointed to organize an exhibit of Cornish mining at the Imperial International Exhibition, for financial help and a loan of specimens, and in response voted a sum of £10 out of the Society's funds and authorised the loan from the Museum of such specimens as were needed to make the collection at the exhibition worthy and representative of the mineral wealth of the county. The exhibit was organised by Mr. J. J. Beringer, who took 161 mineral specimens of the Society's collection for the purpose. The specimens were sent to London in May and returned at the end of October, and are all safely replaced in their places in the cases. The Council are pleased to announce that the collection gained for the Society the distinction of a commemorative diploma. The Council record with sincere regret the deaths during the year of Lady Warington Smyth and

Mr. T. R. Polwhele. The interest which Lady Smyth always showed in the study of geology and her sympathy with the Society and its welfare continued to the last. Her death is a great loss to the Society as a whole, and a personal sorrow to the individual members and officers. Mr. Polwhele was a lifelong student of geology and a member of this Society for more than forty years. Mr. Polwhele was engaged for some years as an officer of the Geological Survey, and held the distinction of a fellowship of the Geological Society. He was elected President in November, 1895, and awarded the "William Bolitho" Medal at the Annual Meeting last year. The Council have decided that the "William Bolitho" Medal this year be awarded to the Rev. D. Gath Whitley, of Baldhu, Scorrier, in recognition of his careful and useful work in geological research. The Council propose to arrange an annual excursion for the study of the geology of local subjects on the spot at some time in the summer, in the hope that such a step may encourage an interest in the study of the science.

LIBRARIAN'S REPORT.

1909.

THE Librarian acknowledges, with thanks, the receipt of publications from the following :—

American Philosophical Society.
—— Academy of Arts and Sciences.
—— Academy of Nat. Sciences.
—— Geographical Society.
—— Institute of Mining Engineers.
Australasian Association.
Batavia. Jaarbock.
Belgium. Soc. Roy. Zoologique.
Bristol Naturalist's Society.
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Cincinnati. Society of Natural History.
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Minnesota. Academy of Natural Sciences.
Missouri. Bureau of Geology.
Montana. University.
Monte Video. Museo Nacional.
New York Academy of Sciences.
New South Wales. Geological Survey.
——. Royal Society.
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Normandy. Société Geologique.
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Nova Scotia. Institute of Science.
Peru. Cuerpo des Ingeniores de Minas.
Philadelphia. Academy of Natural Sciences.
Plymouth Institution.
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Torquay Nat. Hist. Society.
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Upsala. Geological Institute.
Vienna. K. K. Geologischen Reichsanstalt.
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Victoria. Geological Survey.
Western Australia. Geological Survey.
——. Department of Mines.
Wisconsin. Geol. and Nat. Hist. Society.
——. —— Survey.
——. Academy.
Yale University.
Yorkshire Geological Society.

[*From the Authors.*]

The Origin and Age of the Sedimentary Rocks. J. M. Schaeberli.
Ancient Volcanoes of Devon. A. Somervail.
The Mineral Resources of India. T. H. Holland.
Geological Features at Carpalla Claypit. J. H. Collins.
L'Equilibrio ed il Moto perpetuo della Terra. G. Borredon.
Cassiterite and Specular Iron in the Lodes of Dartmoor. D. A. Macalister.
Petroleums and Coals. E. Coste.
Report on the Magnetic Survey of South Africa. J. C. Beattie.
Overthrusts at Tintagel. H. Dewey.

[*Purchased.*]

Palæontographical Society. Vol. lviii.
London, Edinburgh, and Dublin Philosophical Magazine.

CURATOR'S REPORT.

DONATIONS TO THE MUSEUM.

MR. W. COLENSO :—

Graphite in Grey Elvan, from Polmennor.

MR. J. KNEEBONE :—

Iron from Republic Mine, Michigan.

[*Purchased.*]

Asbestos. South Africa.

Felspar Crystal in Granite.

THE WILLIAM BOLITHO MEDAL,

which is provided for by a fund bequeathed to the Society for the purpose by William Bolitho, of Ponsandane, in 1895, has been awarded to the following members :—

1896. R. Etheridge, F.R.S.
1897. Howard Fox, F.G.S.
1898. J. H. Collins, F.G.S.
1899. F. W. Millett, F.R.M.S.
1900. Sir C. Le Neve Foster, F.R.S., etc.
1901. Thomas Clark.
1902. Dr. Richard Pearce, F.G.S.
1903. W. A. E. Ussher, F.G.S.
1904. J. D. Enys, F.G.S.
1905. Lady Warington Smyth.
1906. A. K. Barnett, F.G.S.
1907. U. Green, F.G.S.
1908. T. R. Polwhele, F.G.S.
1909. Rev. D. G. Whitley.

W. BOLITHO MEDAL ACCOUNT.

Dr.

	£	s.	d.
November 10th, 1909—			
To Gerrard and Co.	12	10	0
,, Balance	7	1	5
	£19	11	5

Cr.

	£	s.	d.
November 10th, 1909—			
By Balance	1	10	5
,, Interest on ditto		2	10
February 15th, 1909—			
,, Half year's dividend on £540 Great Central and Great Western 3% Stock . . .	8	19	6
August 15th, 1909—			
,, Ditto, ditto	8	18	8
	£19	11	5
November 9th, 1909—			
By Balance	7	1	5

STATEMENT OF RECEIPTS AND EXPENDITURE FOR THE YEAR 1908–9.

Dr. *The Treasurer in Account with the Royal Geological Society of Cornwall.* **Cr.**

Receipts.

November 10th, 1909—	£	s.	d.	£	s.	d.
To Balance from 1908				51	1	10
,, Ordinary Subscriptions and Arrears	31	10	0			
,, Subscription per His Royal Highness the Prince of Wales . . .	20	0	0			
,, One Year's Dividend on £1800 Midland Railway 2½ % Debenture Stock, £45, less tax £2 6*s.* 10*d.* .	42	13	2			
				94	3	2
				£145	5	0
November 10th, 1909—						
To Balance in Treasurer's hands				£54	17	8

Expenditure.

November 10th, 1909—	£	s.	d.	£	s.	d.
By Rates and Taxes	0	8	0			
,, Curator's Salary	42	13	2			
,, *Transactions*, Periodicals, Printing, and Stationery	13	15	5			
,, Fire Insurance Premium . . .	2	12	9			
,, Coals and Gas	10	16	8			
,, Repairs to Buildings . . .	2	3	7			
,, Palæontographical Society . .	1	1	0			
,, Grant to Imperial International Exhibition	10	0	0			
,, Mining Map of West Cornwall .	1	1	0			
,, Postages, Carriage of Specimens to London, and Petty Disbursements	5	15	9			
				90	7	4
,, Balance				54	17	8
				£145	5	0

T. R. BOLITHO, *per pro*, *Treasurer.*

LIST OF PAPERS

READ TO AND PUBLISHED BY THE SOCIETY.

1909.

President's Address. W. Colenso.

The Angular Quartz Drift of Cornwall. Rev. D. G. Whitley.

The Raised Beaches and Head of the Cornish Coast. W. Rogers.

Addenda to the Working List of Cornish Palæozoic Fossils. J. H. Collins, F.G.S.

THE ANGULAR QUARTZ DRIFT OF CORNWALL.

By Rev. D. Gath Whitley.

Geology may be studied in several different ways. *First*, we may consider it mineralogically, and confine our attention to describing the mineral character of the rocks. *Secondly*, we may study it historically, by setting forth the life-systems of plants and animals which the rocks contain. And, *thirdly*, we may present it from a picturesque point of view by describing the general appearance of the surface of the land and the effect of the various geological changes on the scenery of the country. This last method has been admirably performed for Scotland by Sir Archibald Geikie,* and in graphic and beautiful language, both for Scotland and many parts of England, by Hugh Miller.† A valuable contribution to this class of geological literature was made some time ago by Mr. D. Mackintosh in an able work,‡ in which he maintained

* In his work entitled *The Scenery of Scotland.*

† See his *Sketch Book of Popular Geology*, and *First Impressions of England and its People.*

‡ *The Scenery of England and Wales: its Character and Origin.* 1869.

the power of *marine* denudation in producing the leading features of the scenery of England. Lord Avebury, only a short time ago, published a charming book* in which he sets forth *atmospheric* influences as the great factors, combined with ice, in producing our English scenery. The literature, therefore, of this branch of geology is becoming very extensive.

It is particularly with the *surface* of Cornwall that I am going to deal in this paper, with respect to some of those last great changes which have occurred since the advent of man. I do not refer to those atmospheric alterations which are ever in action, but to physical and surface changes, which acted powerfully for a limited time and then completely ceased to operate.

I feel, however, that before entering into details, some explanation of the title of my paper is required. I speak of the "Drift," and I use the term purposely. Although considered to be somewhat old-fashioned in these days of Glacial phraseology, it was nevertheless a term used by Lyell, and particularly by Murchison, in describing the Quaternary gravels of the south-east of England.† The term "Drift" is also employed by the present surveyors of the Government Geological Survey, who include in it all those deposits which lie between the latest beds of the Pliocene Period and those superficial

* *The Scenery of England, and the Causes to which it is Due.* 1902.

† "The Angular Flint Drift of the South-East of England." See *Geological Journal*, Vol. VII. 1851.

deposits which are now forming under our eyes. The phrase "Drift" also is useful because it implies that the beds described have not been formed by the disintegration of the rocks *in situ*, but that the materials which compose them are *drifted* into their present position by the action of water. The term "Angular" is also very necessary, since it shows the origin of the gravels and the amount of attrition the particles have received during their transport to the place where they are now found. Thus all gravels may be divided between "angular" and "rounded," and all observation should closely observe this distinction. Thus, in Cornwall we have some patches of gravel formed of large *rounded* quartz pebbles, such as the bed of gravel at Polcrebo in the parish of Crowan, the quartz nodules in which have been rounded and subjected to long attrition through water action. The same may be said of the quartz pebbles in that peculiar patch of gravel on Crowsa Downs, in the Lizard district, where, in the pits, a section shows clay with large rounded pebbles at the bottom, then follows a layer of peat, below which is a bed of shattered angular quartz fragments, whilst the same kind of quartz rubble lies on the surface over the vegetable soil.* Here we have the *rounded* quartz pebbles and the *angular* quartz detritus in juxtaposition, but with their different characteristics clearly demonstrated.

* See *The Post-Tertiary Geology of Cornwall*, by W. A. Ussher, p. 10; also, a paper by Rev. Edward Budge, in *The Transactions of the Royal Geological Society of Cornwall*, Vol. VI, 1842, pp. 91–8.

It is with the latter kind of quartz débris that I propose principally to deal in this paper. I would also mention that in excavating for the foundations of the nave of Truro Cathedral a bed of *rounded* quartz pebbles, some of which were larger than a man's fist, was found at a depth of about twelve feet below the surface of the ground.

In order to simplify the discussion, I will divide the quartz deposits of Cornwall as follows :—

First : The isolated blocks.

Secondly : The subsoil layers.

Thirdly : The surface deposits.

I purposely omit such a solid outcrop of quartz rock as that which is found in Gerrans Bay, near Portscatho, and known as the quartz rock of the "Carnes" in the parish of Veryan. Although a large portion has been broken off, and transported by water action to the beach below, it is hardly a case which comes within my definition of "Drift." I confess that my division above-mentioned is not altogether satisfactory, as the second and first divisions constantly run together. But I am compelled to make such an arrangement for purposes of convenience, and for facilitating a clear method of description ; and although I know that the term "Angular" cannot be applied to many of the isolated quartz blocks in Cornwall, I am forced to unite them with the smaller fragments in order that I may describe them all at the same time.

First, as to the isolated blocks of quartz, which are still found scattered over the surface of Corn-

wall, in all directions. They are so common that they hardly now attract notice, but their position ought to be carefully marked. We find them everywhere. Not only on the barren moorlands, but in the lowland valleys, and by the sides of the streams. On the headlands of our coast-line, which run far out into the sea; in the ruined cliffs, which have crumbled down by disintegration; and in many places lying in numbers upon the beach, where the ceaseless grinding of the sand and pebbles over them by the action of the waves at the highest tides has given to them a beautiful polish. These great white stones, often shaggy with green mosses, and weather-beaten with the storms of ages, the ruins of a world which has long passed away, have originated many a wild romance and legend, and have been a source of much of the fantastic folk-lore of our county.

It must be remembered that they are fast disappearing. There are few that now remain in our cultivated valleys. They are not convenient neighbours to the plough and the harrow, and they have been largely broken up to make roads, to build walls, and to form convenient gate-posts and hedges. Many of them are being constantly removed from our moors and commons to make rockeries in private gardens, or to adorn the public parks. They were far more numerous formerly, and were abundant in many places where none are found now. In my own neighbourhood, I can remember many places on crofts and moorlands which once

were white with great quartz boulders, where not one can be seen now. Many of the finest blocks of quartz in the parishes of Kea and Baldhu have lately been removed to beautify the public parks in Truro, and others are put to more practical uses, and form gate-posts in the neighbourhood. In the early part of last century J. A. De Luc travelled through the West of England, and visited many parts of Cornwall. It is interesting to note that he says that many of the hills in Cornwall were covered with quartz boulders, which he states were even then (1806) fast disappearing. He particularly mentions the neighbourhood of Looe Pool and Lostwithiel.* Dr. Borlase, writing more than fifty years before De Luc, speaks also of the abundance of quartz rocks on the surface of Cornwall, and he also mentions how they were, even then, being destroyed.† The names of old tenements, crofts, and crossings also frequently refer to the former abundance of these quartz boulders in situations where none can be found now. Thus, such names as "Whitemoor," "Blanchland," "Whitestone," "White-hill," and many others similar, show that in former times these neighbourhoods were covered with white quartz boulders, which have now all disappeared. In the eastern part of Cornwall and in Devon the blocks of quartz are known as "White-acres"‡ or "Whitakers," and the frequency

* *Geological Travels*, Vol. III, pp. 298, 304, 305, 363, 366.
† *Natural History of Cornwall*, pp. 90, 91.
‡ *Geology of Cornwall, Devon, and Somerset*, p. 473 (note).

of the name proves how plentiful these great blocks were in former times. The large blocks of quartz called "The Whitakers," in the parish of Tamerton Foliot, about five miles north of Plymouth, form interesting specimens, the largest being ten feet by five, and they have evidently travelled a considerable distance. These interesting boulders have been described at length by my Father,* and by Mr. William Pengelly.† As, then, these great quartz boulders have been destroyed or removed from the surface of our county for centuries, we may be certain that a thousand years ago the hills and moorlands of Cornwall were perfectly white with countless numbers of these huge blocks and fragments of massive quartz.

What is the origin of these boulders, and how came they into their present position? Theoretically speaking, all are agreed, and the problem presents little difficulty. The quartz veins which traverse the Devonian rocks of Cornwall, and which vary in thickness from a mere thread to many feet, and which protrude in many places in our cliffs, fields, and moorlands, suggest at once the source from which the quartz blocks originally came. The parish of Gorran, which is traversed by great quartz veins, which frequently form great rocks or "carnes," not only in this parish, but also in that of Veryan, is a typical instance.‡ We

* *Journal of the Royal Institution of Cornwall*, Vol. IV, 1889.

† *Transactions of the Devon Association*, Vol. XII, p. 311.

‡ *Transactions of the Royal Geological Society of Cornwall*, Vol. VI, pp. 52, 55, 56, 182.

have only to imagine that some great crushing agent passed over the quartz districts of Cornwall, and that then powerful denudations, attendant on a submergence, distributed the débris, and carried the blocks into their present position. We have, of course, to select our transporting agent. Some might, following the example of Sir Henry Howorth,* suggest *water*, acting in a sudden and violent manner. In Cornwall, long ago, this theory was universally held. Carew, writing three centuries ago, says: "The Cornish tinners hold a strong imagination that on the withdrawal of Noah's flood to the sea, the same took its course from east to west, violently breaking up and forcibly carrying with it the earth, trees, and rocks, which lay anywhere loosely, near the upper surface of the ground. To confirm the likelihood of which supposed truths, they do, many times, dig up whole and huge timber trees, which they conceive at the Deluge to have been overturned and overwhelmed."† It is interesting to find that the same belief is still held by the old Cornish miners, showing the vitality of the theory. It also proves, as I set forth in my last paper which I contributed to this Society,‡ that for many centuries trunks of great trees have been found, sometimes whole and sometimes fractured, in our Stream-Tin deposits, proving that these stanni-

* In his valuable work, *The Glacial Nightmare.*

† *Survey of Cornwall*, 1602, p. 7.

‡ *Transactions of the Royal Geological Society of Cornwall*, Vol. XIII, 1908, pp. 237–56.

ferous beds were formed when Cornwall was covered with fine forests and enjoyed a mild climate. The presence of these great trees in our Stream-Tin deposits also demonstrates that these beds were formed rapidly, and by water which swept over Cornwall with tremendous force and rapidity.

It will, however, be more generally held that the transporting agent which carried our quartz boulders to their present position was *ice*, and Mr. C. W. Peach* adopts this view when discussing the distribution of the great blocks of rocks which are common on the downs in the Lizard Peninsula.

Nevertheless, attractive as this view may be, there are serious difficulties in its way, when we descend to details. The glaciation of Cornwall is still a doubtful matter, and we have no right to picture glaciers radiating from the higher portions of our county when the marks of the presence of these glaciers are so completely wanting. The quartz boulders also are frequently found at greater elevations than the outcrop of the quartz rocks from which they are supposed to be derived. Thus, the quartz rocks of Veryan and Gorran could not possibly be the centre from which the quartz boulders on the watershed of Cornwall around Mithian were transported, as the latter district is much higher than the former, and in a

* *Transactions of the Royal Geological Society of Cornwall*, Vol. IX, p. 103.

submergence Gorran and Veryan would be under water, while the watershed would be dry land. Again, where could the great blocks of quartz which are so common on St. Breock Downs come from? There is no higher land in the neighbourhood, except in the granite districts. We have evidently to look to a *distant* source for the blocks that are found at such an elevation. Then there are *climatological* difficulties. How could Cornwall have possessed a climate so cold that all its higher regions were covered with snow and glaciers, whilst, at the same time, the sea which then covered all the lower portions of our county was so *warm* that the icebergs formed from our Cornish glaciers melted almost as soon as they began to float away? Many of the stones and blocks of quartz also are *rounded*, and bear marks of long and continued attrition, which seems to imply that they came from far, and had been considerably rolled about in their transport. Besides all this, we must remember, as a warning not to be too hastily seeking in *ice* a universal means of transport, that there are many tropical regions where the land is covered with erratic boulders which could not possibly have been brought there by ice. Thus in Central Africa, in the regions of the Gaboon, M. du Chaillu found great boulders of quartz scattered over the country* which could not possibly have been brought there by ice, as we cannot imagine a Glacial Period in Equatorial Africa; moreover

* *Adventures in Equatorial Africa*, p. 53.

the mountains are low, being not more than seven thousand feet in height. In the deposits of coal of the Carboniferous Period we frequently find large boulders which cannot possibly have been dropped amidst the coal-beds by the meeting of floating ice.* Or, to take the case of the Stiper Stones near Shrewsbury, so well described by Sir Roderick Murchison † and Mr. Mackintosh.‡ Here several great masses of crystalline quartz rock, averaging more than thirty feet in height, rise at intervals on the top of a level moorland. The wall of quartz was clearly continuous, and it was breached in its weaker parts by some powerful agent, which was probably the sea, which broke through the ridge, carried away the quartz débris, and distributed it over the surrounding uplands, whilst it left the harder portions of the quartz ridge standing in "The Stiper Stones." Such was probably the origin of some of our Cornish quartz isolated masses. Dr. Buckland has also shown that the large quantities of quartz pebbles near Lichfield and Birmingham have been derived from the quartz rock of the Lickey Hills,§ an opinion which was also held by Sir Roderick Murchison.¶

Notwithstanding climatological difficulties, the theory advanced by Mr. Peach to explain the

* *Geological Magazine*, Vol. II, 1885 (New Series), p. 555.

† *Siluria* (1st Edition), pp. 283–6.

‡ *The Scenery of England and Wales: its Character and Origin*, pp. 371–4.

§ *Geological Transactions*, Vol. V, p. 506 (Old Series).

¶ *Siluria*, pp. 492–5.

distribution of our Cornish quartz boulders will probably be most generally held. When a Glacial Period prevailed over large areas of Wales and Ireland, we may fairly believe that when Cornwall was submerged icebergs from these glaciated regions floated over our county and, melting, dropped their quartz blocks on its surface. The distribution of numbers of shattered flints in Cornwall, both in the subsoil and on the surface, favours this supposition. It has been thought that our Cornish flints are the débris of the chalk beds which once covered Cornwall, but were afterwards denuded from its surface. But the extent of this denudation and its complete character, which the supposition requires, renders the theory doubtful. It seems more probable that they form part of the drift of the Antrim chalk, the flints and débris of which can be traced in Wales and down the east coast of Ireland, as well as in the Isle of Man. If, then, these flints have travelled southwards during a period of submergence, and have been at that time deposited over Cornwall, I do not see why the quartz blocks of our county may not have had the same origin.

We now pass to the deposits of shattered and angular quartz, which lie in the subsoil of Cornwall only a foot or two below the surface of the ground. The visitor who traverses Cornwall for the first time is frequently much struck by noticing by the sides of the roads in the mining districts of our county great white piles of broken quartz of regular

form with a perfectly flat top and of great height, length, and breadth. On asking whence these masses of quartz were brought, he will be told that the "spar" (i.e. quartz) was found in great quantities just below the surface of the ground, and that when the commons were enclosed and broken up for cultivation, and also when they were ploughed, the quartz pebbles and fragments were collected, and others were picked off the surface. These were piled up by the side of the road, and were afterwards broken up to form metalling for the roads. On the barren hills of Cornwall, and in the subsoil, the quartz débris has to be removed before the land can be cultivated. In reclaiming land from the commons and moors, the farmer in Cornwall trenches it deeply, digs out the "cold spar," and piles it up by the roads and fences. Mr. Worgan notices this,* and gives an instance of the manner in which the "spar" in the neighbourhood of St. Agnes was cleared out of the soil and subsoil, and then very profitable crops were grown on the land. The same operations are constantly taking place in our moorland districts.

This stratum of shattered quartz lies immediately beneath the vegetable mould, and varies in thickness from a few inches to several feet. The matrix is generally a tenacious yellow clay, often stained red by oxide of iron. The fragments are of all sizes, some being less than half an inch in diameter. It is striking, however, to observe that in the sub-

* *View of the Agriculture of Cornwall*, p. 11.

soil, mingled with the small angular fragments, we constantly find large blocks of quartz, which are often double as large as a man's head, and are even occasionally dug up four feet in length and three in breadth. The number of these quartz boulders is very great; they lie at a depth of from two to three feet below the surface of the ground, and so seriously interfere with ploughing that when land is reclaimed from the moorlands in Central Cornwall, they have to be dug up and carried away. According to Carew, the centre of Cornwall was in his day (i.e. in 1602) a waste,* and these great quartz boulders at that time must have been as plentiful in the subsoil as they were on the surface of the widely extended moorlands.

It is very instructive to observe the different ways in which the small quartz fragments are distributed in the subsoil. As a rule they are shattered and angular, their edges being generally quite sharp. They lie at all angles, and in some places are congregated in masses and bunches, as if they had been piled up by sudden and violent rushes of water. In fact, as a rule, they are accumulated helter-skelter, and lie in the utmost confusion. The larger quartz blocks are often in a *vertical* position, pitched in upon their ends, and standing upright, as though they had been dropped in this manner. This is strikingly exhibited in the face of the earthy cliffs which form the upper part of the North Cliffs near Camborne. Here the great quartz boulders

* *Survey of Cornwall*, p. 6.

may be seen *standing upright* in great numbers in the middle of the earthy cliffs, and looking like great sheets of white paper. It is possible, of course, that the dissolving of the earth around them may have occasionally caused them to alter their position, but the uniformity with which such numbers of these boulders stand upon their ends goes far to negative this supposition. On the other hand, the *linear* arrangement of the angular quartz fragments is often visible in cliffs and quarries. Thus, on the coast near Newquay, at Pentire Head, the upturned strata of Devonian rock may be seen lying inclined at a very high angle. Over the top of the edges of these strata there lies a thin line of angular quartz fragments. This line is parallel with the surface of the ground, and is only a few inches thick. It is covered on the top by about six inches of vegetable mould, and must be about 150 feet above the level of the sea, on the top of the hill. Again, on the top of the hills, about 200 feet above the sea, between Portreath and Porthtowan, there is a long straight line of shattered quartz fragments, which can be traced for hundreds of yards. The average width of this band or line is about six inches; above it is the soil, which is without quartz, and below it is the Devonian rock, which also contains no quartz. In the quartz band the fragments are small and angular, and they lie at all angles in the matrix of clay.

Now, how came this bed of shattered angular fragments of quartz, which we find in so many

places in Cornwall, immediately beneath the subsoil, to be formed? Are we to conclude that it originated *in situ* by the disintegration of the subjacent rocks? A brief consideration of the facts will show us that it cannot have originated in this manner.

First. The great extent of the area over which the subsoil is full of shattered fragments of quartz and of great quartz blocks negatives this supposition. The quartz is found distributed over scores of square miles in central Cornwall in one continuous sheet, while the quartz veins only occur here and there, and are, as a rule, only a few feet in breadth.

Secondly. The shattered quartz is constantly found in the subsoil where the subjacent rock is entirely of a different nature, such as elvan; and even in many places where the killas lies beneath the layer of shattered quartz, we find that the killas contains no quartz at all.

Thirdly. When the subjacent rock consists of elvan it is only here and there that we find the elvan shattered in the same manner as we find the quartz to be.

Fourthly. In many localities in Cornwall thick beds of consolidated sand are interposed between the layer of shattered quartz and the subjacent rock, while the quartz débris is often divided into bands by the intervening beds of sand. The earthy rubble in the cliffs at Godrevy and Perranporth furnish good instances of this.

All this proves that the stratum of shattered quartz could not have originated *in situ* by local

disintegration, but must have been transported to its present position by powerful aqueous action.

It is curious to note that in Northern and Central France there is a great deposit of mingled clay and gravel, and in this bed, which covers the hilltops and tablelands, and is called *Diluvium Rouge*, shattered fragments of quartz frequently occur.* The same nodules of quartz are found in the clays which cover the plateaux in the Department of Charente.† These French deposits are supposed to have originated by vast aqueous cataclysms, which occurred during the melting of the ice-sheets at the close of the Glacial Period. Speaking of the formation of the *Diluvium Rouge*, M. Belgrand says: "It was a veritable sea of mud which was moved."‡ So Professor Dupont describes a thick deposit of yellow clay, with limestone and quartz fragments, which covers the hills in many parts of Belgium, and descends into the valleys.§ This is the equivalent of the *Diluvium Rouge* in France. Along the western slopes of the Ural Mountains Erman says¶ that there is a thick deposit of clay full of shattered fragments of quartz, which lies immediately beneath the vegetable mould. Beneath this layer of clay and quartz lie the gold-bearing

* *Le Limon des Plateaux du Nord de la France*, by M. E. D'Acy, p. 12.

† *Memoirs*, by M. A. Rochebrune, p. 53.

‡ See a paper by him at the Anthropological Congress at Brussels in 1872. *Comte Rendu*, p. 133.

§ *Étude sur Le Terrain Quaternaire des vallées de la Meuse et de la Lesse, dans la Province de Namur*, p. 41.

¶ *Travels in Siberia*, Vol. I, pp. 220, 254.

gravels. Now the same philosophical observer tells us* that the auriferous sands and gravels of Western Siberia lie *immediately below* the stratum of earthy rubble which contains the bones of the great Quaternary mammalia†: hence it seems clear that the Quaternary Age of the quartz rubble is perfectly demonstrated. Our Cornish layer of shattered quartz overlies the stream tin-beds, which are the equivalents of the auriferous and mammoth beds in the Urals, and it clearly follows from this that the quartz rubble in the subsoil of our county was formed during the Quaternary Period.

The thin layer of quartz débris, which is spread over the surface of so many of the moors of Cornwall, is familiar to every observer. Sir Henry De la Beche notices it,‡ and remarks on the manner in which it renders the soil unfertile. This layer is merely the top of the bed of quartz before described, which has been disintegrated by atmospheric agencies. The characteristics of this surface layer of quartz débris are: (1) The fragments are very small. (2) They are all angular. (3) They are evenly distributed and do not lie in heaps. Another characteristic is, that the quartz is often seen to be distributed in wave-like sheets over the flat surfaces of the moors, which clearly demonstrates the action of water in spreading it out over the surface.

How were these great sheets of quartz débris

* *Ibid.*, Vol. II, pp. 88, 89.

† i.e. the mammoth, rhinoceros, and musk-ox. ‡ *Report*, p. 473.

formed? Sir Henry De la Beche thought that they originated through the decay of the subjacent quartz veins; but the veins are too thin and too local to give rise to such a general and widespread phenomenon, and in many places the subjacent rock is either clay-slate without any quartz, or is formed of elvan. The minute quartz débris also has not only been shattered, but evenly distributed, and spread out in thin sheets, over scores of square miles in the upland districts in Central Cornwall. A thin layer of quartz gravel lies spread over the desert plains of Central Asia,* which have been proved to have been under water in comparatively recent geological times.

That this quartz layer is, in Cornwall, very recent, is proved by its position. Doubtless, we must be careful to avoid pitfalls, and we ought always to remember the words of Professor John Morris, that a gravel may be of any age "between the Bagshot Sands and the moon!" Still, when we find this thin sheet of quartz gravel lying over the Quaternary sands of St. Agnes Beacon, and also over our stream tin deposits, we shall not be wrong in considering it to be of Quaternary Age. The question of the manner of its formation is not so easy to answer, although we may say generally that it was formed by the grinding down of the rocks containing quartz veins, and by the spreading out of the débris by water action. In the gutters by the side of the roads on our Cornish hills, we see

* Erman's *Travels in Siberia*, Vol. I, p. 361.

similar deposits being constantly formed on a small scale. After heavy and long-continued rain, diminutive beds of clay may be found in these gutters, covered by a thin crust of minute quartz fragments. We have only to imagine great bodies of water to sweep over a district covered with the débris of broken up quartz rocks, and the solution of the problem is before us. On the plains of Western Manitoba the Quartzite Drift is spread over the surface of the ground for hundreds of square miles. This Drift contains no marine mollusca, and it lies evenly over the Tertiary deposits. Professor G. M. Dawson,* in describing it, considers that it was formed in this manner. During the Quaternary Period, Western Manitoba was submerged beneath a shallow sea. Icebergs broke off from the glaciers of the Rocky Mountains, and melting, dropped their loads of quartz débris on the submerged land beneath. Then the land rose *rapidly*, and the currents set up in the retreating water rearranged the detritus, and spread out the quartz débris in even sheets over the surface of the land.

Such seems to me to have been the origin of our surface deposit of quartz. It seems not improbable that the shattered fragments of flints, which formerly lay in such great numbers on our moorlands, an are even now to be found on our commons an unenclosed lands, were drifted there from Irelar during a submergence in the Glacial Period. Cha

* *Quarterly Journal of the Geological Society of Great Brit* No. 124, 1875, pp. 603–24.

flints and hard pieces of Antrim chalk are found, according to Professor Jukes,* in the drift, along the whole eastern and southern coast of Ireland. Our flints, then, in Cornwall, may have been drifted southward during the Quaternary Period, from their original home in the chalk of Antrim.

I think it probable that during the Glacial Period, when Wales and many parts of Ireland were covered with glaciers, Cornwall was, in most part, submerged beneath a shallow sea. Icebergs detached from the ends of the Welsh and Irish glaciers, floated over our Cornish districts, and, melting beneath the influence of the warmer waters of the Gulf Stream, dropped their loads of quartz gravel and boulders upon our submerged Cornish lands. The duration of this submergence was not long, for the quartz gravel was not under water long enough to become rounded from the grinding action of the waves. After a time, probably towards the middle of the Quaternary Period, Cornwall rose out of the icy waters of the Glacial Sea. During this uprising of the land, currents were set up, which, by their sweeping action, spread out the quartz débris uniformly over the land, and distributed it evenly in a thin sheet, over the surface. Since this elevation, at the middle of the Quaternary Period, the surface of Cornwall has never been under water again.†

* *Manual of Geology*, p. 675.

† I regard the downward movement, shown by our submarine forests—which took place in the Neolithic Period—as of a very slight character, which did not affect the inland parts of Cornwall.

Such a picture of Cornwall, in prehistoric days, may not be attractive. A slowly sinking land under a gloomy sky, and, ever and anon, veiled in the white shrouds of protracted snowstorms. Beaten by the icy billows of a wintry sea, and swept by the storms of Arctic winters. With snow covering its desolate uplands, and countless icebergs stranding on its shores, and grating on its shallows, must have presented a dreary and melancholy prospect, had there been human eyes to look upon it. Nevertheless such seems to have been the manner in which stern Nature operated by her severe laws upon the surface of our county, in order that it might become in due course of time, a land—
"Made blithe, by plough and harrow."

THE RAISED BEACHES AND HEAD OF THE CORNISH COAST.

By Walter Rogers.

After all that has been written on this subject further discussion might seem superfluous. But I think it will be admitted that the theories on the subject have not yet been conclusively proved or disproved, and that a careful review of current theories, testing them by observed facts, may not even now be quite useless.

I have for some time past been carefully studying the coast of Cornwall, and have endeavoured to collect a mass of observations which may elucidate, and in some ways modify, current theories on the subject.

In this matter, as in all others connected with the geology of the county, we are fortunate in having as authoritative handbooks the recent memoirs of H.M. Survey. In these memoirs the Raised Beaches, Head, and Stream Tin Deposits are classed as Pleistocene; the Submerged Forests as Recent.

The Pleistocene Period is generally considered to begin with the Glacial Age, and covers the

period of Palæolithic man and the Pleistocene mammals. Now, as no traces of glaciation have been found in Cornwall, or indeed south of the Thames, it is supposed that the climate of Cornwall was subarctic, and that frost, snow, and thaws caused the formation of the Head—rocks, stones, and earth sliding together in a semi-liquid state down the slopes, and finding rest on the coastal shelf.

This theory is supported by what may be called physical evidence only, for organic remains are very scarce in the Raised Beaches, and entirely absent from the Head. In attempting to confirm the theory, and date the deposits by organic remains, responsible and irresponsible persons alike have made some unwarranted assumptions concerning the absence of (1) fossil shells, (2) remains of Palæolithic man, (3) remains of Pleistocene mammals.

1. Fossil Shells.

These are, on the whole, conspicuous by their absence in the Raised Beaches of Cornwall, though generally present in those of Devonshire.* The only shells or remains of marine organisms that I have found, during a careful survey of nearly the whole coast from Plymouth to Padstow, are :—

A. Vegetable Coral in a deposit undoubtedly to be referred to the Raised Beach at about six feet under the ground, in the flat part of the graveyard at Mylor, on the Fal Estuary.

* For this statement, and for information about Slapton Beac I am indebted to Mr. R. Hansford Worth, F.G.S.

B. Some doubtful limpet-shells thrown out by rabbits from the Raised Beach at Grebe Point, near Portscatho. These certainly had Raised Beach gravel adhering to them, but I failed to find any shells *in situ.*

C. Part of one oyster shell at Godrevy.

D. Comminuted shells in the sand and consolidated sand at Godrevy, Fistral Bay, Trebetherick (Padstow), Pendower (east side), and in the fine shingle from a doubtful Raised Beach at Constantine Island (near Trevose).

E. Shells in the Raised Beach at Fistral Bay and on either side of Towan Head, Newquay:—Ostrea, Patella Vulgata, Purpura Lapillus, Mytilus Edulis, Littorina Littorea, Glycimeris Glycimeris (doubtful). Also fragments (doubtful) of Saxicava or Pholadidea, Tapes Pullastra, Cardium Edule, and Anomia Ephippium.

All these are modern species, and there is nothing in them to indicate any age except the present. They may be either Pleistocene or Recent.

Now, as to the scarcity of shells, it is assumed that there were shells in the Raised Beach, and that they have been dissolved away and the deposits become "decalcified." This is a mere assumption. If other shells were dissolved, why not those which I have mentioned? And why are no casts found? It is evident that the shells do not dissolve away. They become fossils, if large enough: if comminuted, they are to a certain extent dissolved and bind the sand into sandstone.

2. Remains of Palæolithic Man; and 3. of Pleistocene Mammals.

The only traces of our supposed ancestor are (1) an entirely unauthenticated weapon from the Lizard district, now in the British Museum; (2) the supposed remains of a Palæolithic floor at Prah Sands, on which I can offer no opinion.

But it is sometimes assumed that because his remains are found in Devonshire, therefore he also existed in Cornwall; and that because the Hyæna, the Cave-Bear, the Sabre-toothed Tiger, and the Rhinoceros Tichorhinus roamed the land of Devon, therefore they also were found on this side of the Tamar.

These are also assumptions; and if we confine ourselves to the facts, we can only say that we have no proof that Palæolithic man or Pleistocene mammals ever existed in Cornwall, or that shells were found on the beaches, except in a few favoured spots like Newquay. Instead of assuming that these things existed and are lost, we may just as well try to imagine a state of things in which Cornwall was uninhabited by man or beast, and the neighbouring seas devoid of life, or at any rate of shell-fish, except in a few places.

The Recent Period includes the Neolithic Period, which may have begun five thousand years ago; and Mr. Clement Reid (*Geographical Journal*, November, 1906) puts the commencement of the subsidence which submerged the forests, at about

four thousand years ago. This agrees very well with the flora, fauna, and human remains found in the forests. It is generally supposed that the end of that subsidence brought the land to its present level, which is probably ten or fifteen feet below that of the Raised Beach Period, and that the erosion of the Head overlying the Raised Beach has taken place in recent times, with the shore-line at its present height.

This I wish to dispute, and to show that either—

(1) The Head was to a great extent eroded before the elevation which made possible the growth of the forests.

Or (2) more probably, the subsidence which submerged the forests brought the coast-line to exactly its former level, and that then the greater part of the Head was eroded, and that subsequently the land rose ten or fifteen feet.

RAISED BEACHES, or more accurately the Early Pleistocene Shore-line, may be recognised by the following signs:—

(1) A fringe of varying thickness of pebbles or sand along a line a few feet above present h.w.m.

(2) A planed reef, or "Wave-Platform," raised a few feet above h.w.m.

(3) "Ancient Boulders," obviously not worn by the sea at its present height, and lying on the old Wave-Platform.

(4) Cliffs of Head, which indicate an old shore-line, whether they cover a Raised Beach or not.

The Raised Beaches are composed of boulders, large or small; shingle, generally local, but containing a few flints and other foreign pebbles; sand, washed or blown into its present position.

Boulders.—These are frequently found incorporated in the Raised Beach, or in the base of the Head. They are also found loose on the Wave-Platform, and then it is very difficult to tell whether they were actually part of the Raised Beach, or only masses of rock which fell from the Head and were smoothed by the waves as the Head was eroded. Probably, when they are angular or half-rounded, especially when rounded only upon the seaward face, as often happens, they belonged to the Head. When well-rounded, they belonged to the Raised Beach. Some were perhaps stranded by shore-ice; but this is doubtful.

The *Shingle* of the Raised Beach contains, besides pebbles, semi-angular and angular stones. Now, it is true that any sea beach may contain such stones. I have myself picked up on Gyllyngvase Beach between spring and neap h.w.m., on a surface of less than a square yard, fifty angular and semi-angular pieces of killas and quartzy killas. But it is certain that in a great many instances, if not generally, the Head is mixed with the Raised Beach; and further, it is probable that when the Head came down on to the shore, it was often washed into half-rounded gravel. The base of the Head, or the top of the Raised Beach, presents this appearance in a great many places.

Flints frequently, perhaps generally, occur. I have found them at Rame, Portwrinkle, Spit (Par), in the Falmouth, Manacles, and Land's End districts, in the Mount's Bay, and on the North Coast.

As to the occurrence of other foreign pebbles, I cannot speak with certainty. It is unfortunate that at the place where most foreign pebbles are found on the modern beach, i.e. the Loe Bar, the Raised Beach has been almost entirely washed away.* It is almost impossible to say whether flints are as common in the Raised Beach as on modern beaches. On a modern beach one can roam at will over the surface; of Raised Beaches one only sees a section. I can only say that I have never noticed in the Raised Beaches a large proportion of flints; whereas on the modern beaches between Portholland and Porthluney the proportion (on the surface) is as much as 50 per cent. On the Loe Bar it rises in some places as high as 80 per cent.

Sand.—This is of various degrees of fineness, and is often mixed or interbedded with the shingle, and occasionally lies under it. (A striking instance of this is seen at Bream Bay, where a layer of shingle eight feet thick overlies a thick bed of sand, and is separated from it by a layer of flat stones.) Most of the sand is above the shingle, and passes up into beds of brown or buff-coloured sand of considerable thickness. I have seen these deposits reaching as high as 80 feet at Polhawn (Rame),

* Perhaps there is sufficient left by the Gunwalloe fishing cove to enable a comparison to be made.

80 feet at Fistral Bay, 100 feet at Bream Bay. To reach these heights, the sand must have been *blown*. The highest point at which I have observed an ordinary Raised Beach is 30 feet above h.w.m., near Mainporth. This "blown" sand is rarely calcareous. I have found the loose sand calcareous only at Trebetherick (Padstow); but there are deposits of consolidated sand, calcareous, obviously belonging to the Raised Beach, and probably blown, at Gidley Well, Godrevy, Fistral Bay, and Trebetherick. When examined under the microscope, the loose sand is seen to consist chiefly of quartz grains — angular, semi-angular, or well rounded. Sometimes the well-rounded grains are few, sometimes they predominate. At the Docks, Falmouth, the sand is much coarser below, and contains a large proportion of flattish rounded pieces of killas; in fact, it passes into a sand or gravel which looks just like fine Head washed by the sea; and it is not at all improbable that the fine Head, passing into and being washed by the sea, was returned by the sea as sand, which, on becoming dry about h.w.m., was blown up the shore to varying heights.

This fine brown sand nearly always contains flakes of killas, which fell or were blown into it, as happens with the modern blown sand. Sometimes it is full of flakes, and often the upper part of it is *interbedded with the Head.* It does not appear ever to have formed extensive dunes. At Pendennis, on the east side, the sand is entirely

covered by the Head, and has only been exposed in a sort of quarry, and during the excavation of foundations for a covered pit on the slope. At Fistral Bay it is to a great extent covered by Head, and its upper limits are only disclosed by building operations on the slope. At Polhawn (Rame) a part of the sand is covered by a bank of Head, the lower edge of which slopes at an angle of about 25° with the horizontal. And in many other places the sand is partly covered by Head. In fact, we may conclude that at the end of the Glacial Period it was entirely covered up.

These deposits of old blown sand are more frequently met with in the neighbourhood of Falmouth than elsewhere; but, if we consider the accidental nature of the circumstances which have preserved or exposed them, it would be rash to assert that they were more frequently formed on the South Coast than on the North. On the other hand, if we consider deposits of modern blown sand, we find that the quantity on the North Coast is enormously greater than the quantity on the South.

Modern blown sand can be distinguished from old by its colour, composition, and geological position. It is yellow rather than buff; calcareous rather than quartzose; and it lies over the Head, or "Country," not underneath it. At Gwithian, on the south side of the Red River, near the Strap Rocks, old and modern sand are seen close together, separated only by a thin line of stones or stony Head (section 12). In fact, the Head is the

stratigraphical and chronological dividing-line between the old and the modern sand. The modern sand must have begun to blow at some time after the Head was deposited; but whether at once, or only after the coast-line had settled to its present level, would be a very curious and interesting question. It is quite likely that in our sand dunes will be found the key to the "Recent" history of the Cornish coast.

What was the volume of the ancient beaches?

Some of the sections are very thick, and Raised Beaches are found along stretches of coast which are now chiefly rocky, and contain beaches only in tiny coves; and we may easily conclude that there was more shingle on the coast then than now. If so, what has become of all this shingle, and of all the great volume of stuff from the erosion of the Head? Is shingle decreasing, and sand increasing?

In some places the modern beach is in a different position from the old one. On a beach called "Under the Long Lodge," opposite to St. Mawes, the modern shingle is confined to the northern end, the ancient shingle to the southern end.

The pebbles and sand of the Raised Beach are sometimes loose, but generally they are consolidated; either loosely by mud or clay, or firmly by iron, manganese, or carbonate of lime. Layers and patches of consolidated beach are frequently met with on the Wave-Platform, some distance from the foot of the cliff—10 paces at Nelly's Cove (Porthallow), 30 paces at Godrevy. This shows

that the Head covered up the beach long enough for it to become consolidated by percolation of mineral solutions from the Head.

The sand of the Raised Beach is, in a few places, e.g. Newquay and Godrevy, cemented into sandstone by carbonate of lime derived from the sand itself. From a close observation of modern blown sand, it appears that cementing only takes place *where percolation is arrested;* the modern sand is frequently cemented where it rests on the "country." The hollows in Perran Towans and Godrevy Towans are full of flakes of modern sandstone; at Hemmick Cove, near the Dodman, the blown sand is cemented where it rests on the Head. Evidently calcareous sand resting on a Wave-Platform would present a case of arrested percolation. Probably the calcareous sand at Trebetherick has only escaped cementing in places where the proportion of calcareous matter is small.

The Head is also in many places consolidated into a breccia :—

(1) At the base of a cliff, by pressure or mineral solutions. I have noticed this in the Falmouth district, at Downderry, the Dodman, and under Acton Castle.

(2) Where there is blown calcareous sand resting on it, or mixed with it, as at Newquay, Perranporth, Pendower, and Trebetherick, the calcareous matter cements the Head into a fairly hard breccia.

Two other points remain to be noticed.

(1) At various places round the coast, there are

small beaches resting on the old Wave-Platform. These I call "High Beaches." In many cases they are evidently storm beaches. But in some cases their position is such that it hardly seems possible that they should have been thrown up there by storms; and they may be doubtfully considered relics of the Raised Beach, loosened, but not entirely swept away. Examples may be seen at Pendower East, Fistral West, Turbot Point, and Chapel Point, and at many other places not so convincing.

(2) A few Raised Beaches seem to partake of the character of river gravel; i.e. to have come down from higher and older deposits.

A. The pebble-bed at the brickfields, Marazion Marsh. This is referred by Mr. Clement Reid to an Eocene river gravel. When the G.P.O. were laying their pipe-track along the Hayle Road, I traced pebbles in the subsoil up to the top of the hill at the one hundred feet contour.

B. The pebble-bed at the top of the Greenaway Cliffs, Trebetherick. Mr. Ussher considered this to be a river gravel. He says that it rests on Head. It seemed to me to rest on brown sand. The pebbles and semi-angular flints and cherts are very like those of Marazion. The bedding is different from that of a Raised Beach; and in its upper part it is interbedded with crushed killas. This seems a small point, but it is very characteristic of the Head, i.e. of a moving body from above. The Head frequently, perhaps always,

crushes and carries with it the upturned edges of the strata over which it moves.

C. Spit, Par. This is generally called a Raised Beach. But, though the lower part certainly appears to have been arranged by the waves, the upper part shows the contorted and festooned bedding so characteristic of the Head; and in one place it is interbedded with crushed edges of killas. Moreover the gravel occupies the whole spit from top to bottom of the cliff, and is not covered by Head, except at the foot of the slope towards Crinnis.

The HEAD, which fringes so much of our coasts, and probably is widely, if thinly, distributed over the interior, forming the subsoil, must have come down from above: it positively cannot have come from anywhere else. It is found in its most characteristic form in the killas districts, for those rocks lend themselves most readily to disintegration. In an igneous district it takes a different form; on the granite it consists of boulders and growan, instead of clay, earth, and stones.

Along considerable stretches of coast, e.g. in Falmouth Bay and Gerrans Bay, it must have been practically continuous, except at the headlands; it may have been continuous from Rame to Looe. From the Hore Stone to Mevagissey it does not seem to have been plentiful. In the Lizard district there is hardly any Head, probably owing to the nature of the coast-line.

In the Land's End district it generally assumes the form of boulder slopes, ending in a cliff of boulders and growan, as at Tregiffian, near Sennen, It is very difficult to say what is Head, what is Raised Beach, in such a district; granite weathers into boulders, which weather round; and it is difficult to say whether they have been rounded by the waves; only very well-rounded boulders and pebbles can be safely assigned to the Raised Beach. At St, Loy there is growan under the Raised Beach. The difficulty is farther increased by the presence of river gravels in most of the valleys. At Portheras Cove there seems to be a river gravel overlying a Raised Beach. At Nanjulian Cove a river gravel simulates a beach.

Incidentally it may be mentioned that the Raised Beaches and Head in the Land's End district occur in positions which prove the coast-line to have been practically the same in glacial times as at present, and effectually dispose of the foolish legend (which even now is sometimes seriously quoted) of the submergence of Lyonesse in historical times.

In the killas district along the north coast of Cornwall very little Head now exists, but it is evident that the Atlantic breakers have encroached very much, and the Pleistocene coast-line may have been very different from the present one.

When was the Head formed?

We cannot date it from its organic remains, for it contains none.

The Diluvial Theory is now generally given up, and we can only presume that it was formed under rigorous conditions such as probably prevailed in Cornwall when the great ice sheet covered the greater part of England not very far to the north. There must have been a great deal of snow and frost in Cornwall at that time, and possibly no vegetation. In the winter the soil, if there was any, would be frozen to a considerable depth and covered with snow, and the rocks would be shattered by the frost; and every spring—if there were springs in those days—thaws and rains would bring large quantities of stuff down the slopes; some of this would be deposited on the coastal shelf, some would go into the valleys and be washed away by the torrents, which were sufficiently discriminating to leave in convenient positions most of the tin-stone.

This is the generally accepted theory, and an examination of the available sections on the whole confirms it. Near promontories or bluffs the Head is generally stony and often what I should call "tumultuous"; i.e. the stones are arranged in all directions, as in a talus. But in other places, the bays and small indentations, it is generally stratified, indicating seasonal accumulations. The lines of stratification show the Head banked fairly steeply against cliffs, but lying flatter further out, and assuming on an average an angle of from 5° to 15°. Usually the Head is finer below, coarser above; sometimes fine or coarse throughout.

Sometimes a line of stones lies flat over finer strata and unconformably to them. Sometimes the upper layers seem to have disturbed and to a certain extent rearranged the lower. Often the strata are strangely crumpled and contorted, recalling the contorted strata of the killas or of the Drift in East Anglia. Sometimes the bedding is festooned or overfolded; this feature it shares with the Crowsa gravel, which may have been rearranged in the Glacial Period.

I cannot help thinking that a careful study of the contortions of the Head by a competent person would reveal the movements which took place in it.

In two places, Downderry, and on the east side of Carrick Roads, I have observed the colour-banding (green and purple) of the rocks passing up into or reproduced in the Head.

Sometimes the Head contains, besides angular stones, large blocks of stone with the edges rounded and the surface smoothed, like the quartzite blocks of the Meneage district, or the quartz and quartz-breccia blocks of Northern Cornwall. Such blocks have been searched in vain by many persons for ice-scratches. They must have travelled some distance.

The Head often ploughs into the beach in waves; a very good instance of this was observed on the eastern side of Towan Beach, St. Anthony in R. (section 2).

Further, the base of the Head is constantly

mixed with the Raised Beach, often intimately; and in a few places (sections 1 to 4) the Head and Raised Beach are interbedded. And pebbles are frequently found incorporated in the Head, even up to the top of low cliffs. These must have been picked up in the mass of Head as it moved over the beach.

The top soil nearly always contains pebbles. These may have been brought in the oar-weed during cultivation or thrown up in the spray of the waves. Compare the action of the waves at Trevose Head, where the soil is entirely washed away from the top of the cliff at heights of from fifty to one hundred feet above h.w.m.; at Porthleven, where the waves lodge pebbles right on top of the cliffs; and the Bishop Rock Lighthouse, Scilly, where, after storms, sand is sometimes found in the gallery 120 feet above the sea. Near Porthbeor beach, St. Anthony in Roseland, I noticed a curious section which I cannot explain; a small depression about one hundred feet above the sea, filled with Head, which contained pebbles down to a depth of ten or twelve feet.

In certain bays the cliff of Head is capped by modern blown sand. Now, a moderate cliff is not sufficient always to stop the blowing of sand; but, if sand surmounts a perpendicular cliff, it must leave its traces on the face. The cases I allude to are such as Perran Sands (Marazion), Fistral Bay, Gunwalloe, Towan Beach and Pendower, near Portscatho, and Kennack. Here evidently the

sand must have blown up a slope, which was subsequently eaten into by the sea, exposing a cliff of Head capped with sand.

In some places a considerable deposit of shingle is noticeable at the top of the cliff. This has either been carted there, or is an indication of a kitchen midden. There seem to be several such round the east shore of the Carrick Roads, Falmouth; one of them has been noticed but not explained in the *Survey Memoir* (Falmouth, p. 94). The best example that I have noticed is not in Cornwall, but in Devonshire, at Peartree Point (Start), where a thickish band of pebbles at the top of the low cliff of Head attracts attention, and at first gives the impression that somehow the Raised Beach has got on top of the Head. It appears, however, that this was a small plateau inhabited by ancient man; flint flakes and cores are plentiful; there is a trace of limpet shell, and the shingle appears to have been a somewhat unusual part of his furniture.

At Chapel Point, near Mevagissey, there is a thickish and persistent band of pebbles at the top of the Head; no flint flakes or other signs of ancient man were observed. The pebbles may in part be due to a road up from the beach, which has evidently been shifted, but the shingle continues with such persistence up the slope above, that it can hardly be explained as brought in the oar-weed or for the metalling of roads; and a gravel-bed seems to be the best explanation.

Erosion of the Head.

As was mentioned above, the Head has been considerably eroded. A bank of Head at the usual slope, carried out from a hundred foot cliff till it met the sea-line, would give a coastal fringe of about four hundred yards broad. It is possible, but not likely, that the Head might have terminated in a snout before it reached the sea-level. In one or two places, such as Hannafore (Looe), Penarrow Point (Mylor), Basore Point (Marazion), we see the Head, protected from erosion, tapering away almost to nothing. But in most places it has been eroded to a great extent, or entirely removed.

When did this erosion take place?

In some places, as, for instance, near Marazion, the Head is still being eroded rapidly; in others, as at Downderry, the erosion is intermittent. In other places the sea has eroded it at some former time, has ceased, owing to the rise of the Wave-Platform, but is gradually eating its way through the protecting rock to erode the Head again, as at Bream Bay, Falmouth. In other places, it is protected by the old Wave-Platform, raised some feet above h.w.m., and, though it has been eroded formerly, it is now only within reach of the waves in exceptional storms at spring tides, and *erosion has ceased.*

Rocks, whether above or below h.w.m., do protect the shore. Head itself, though firm enough as a foundation to a house, offers very little resistance to the waves, and *must* be eroded by

them, unless it is protected in one of the following ways:—

1. A rocky foreshore, with reefs either parallel to the shore, or at right angles to it, protects the Head, as we see at Basore Point, which is protected by the Grebe and other reefs, and at Downderry, where reefs at right angles to the shore act as groins, holding up the shingle.

2. In other places, a promontory affords protection from the most destructive waves, as at Newlyn, the west side of Pendennis, and the north side of Pentire Point East.

3. Lastly, an elevated rock platform protects the Head from erosion. A sufficient and conclusive example of this, amongst many others, is the stretch of Head on a raised Wave-Platform at Newporth, between Sunny Cove and Mainporth, near Falmouth. Here the Head was once eroded to a perpendicular face, but it has slipped to the angle of repose, and is thickly covered with vegetation; clay oozes out of the foot of it, forming soil on the rocks, which soil is covered with grass and sedge. I have even seen gorse growing on the Wave-Platform at Hannafore (Looe). Vegetation of this kind cannot grow on a place which is at all frequently washed by the sea. And if such a place is occasionally washed, the Head cannot be eroded, unless the talus is first removed.

Suppose that at one time or another the sea has eroded a perpendicular face in a bank of Head. If, later on, talus accumulates at the foot of that

face, evidently the sea must have ceased to wash it habitually. If, too, that talus becomes covered with vegetation, the sea cannot visit it except rarely. If, further, the Wave-Platform in front becomes covered with vegetation, it is evident that the visits of the sea, if they ever occur, are not sufficient even to scour the Wave-Platform. Of course, it is quite possible that fifty or a hundred years ago the storms may have been more violent than they are now, and many seismic waves are recorded in the middle of the last century; but the further back we go the more effective must have been the barrier opposed to the waves by the Raised Beach Platform.

We will assume that the old Raised Beach has been deposited, and the Head come down on to it, covering it up entirely and extending far beyond it seawards (for very few beaches form anything more than a fringe along the shore). Then the Head must have lain there long enough for the underlying beach to have been consolidated in most places by percolation of mineral solutions. Whether the sea began attacking it at once we do not know, nor how long it took to wear it back to its present cliff-line; but I think we must allow that the sea must have eroded a great part of it before the land rose to its present height, i.e. when the land was at its old level, marked by the Raised Beaches.

Was this before or after the period of the Submerged Forests?

If before, we have to explain the extraordinary

freshness of the wave-markings on the old Wave-Platform. It is smoothed and furrowed (across the grain) and under-cut, just like the present Wave-Platform; even (in one place near Portscatho), where the rocks are so soft that it does not appear possible that the wave-markings should be preserved on them. Also, during the elevation of the land required for the growth of the forests, the Wave-Platform would have become much more thickly overgrown than it is now, and Neolithic man could hardly have failed to make his dwelling on it.

The most plausible conclusion seems to be that the Head was not eroded till after the Forest Period, and that the last movement of the coast-line was more recent than is generally supposed.

The submergence of the Forests must have brought the coast-line to a level almost identical with that of the Raised Beach Period, and subsequently the coast rose ten or fifteen feet, somewhat unequally* and gradually, for a sudden rise would have rendered the country uninhabitable.

Possibly it is still rising. The contrary cannot be proved.

VALLEYS, according to the theory of melting

* The exact difference in height cannot be determined; obviously there is a great difference in height between the top and the bottom of a beach, and we cannot tell whether any given patch of shingle was high up or low down on the ancient beach. The highest patch of bedded sand or shingle that I have observed is near Mainporth, at least thirty feet above present h.w.m. On the other hand, other patches are found very little above h.w.m.; some possibly below h.w.m.

snow, must have contained torrents in proportion to their size, which, if large enough, deposited the stream-tin and swept away the Head. Compare, in this respect, the two valleys at Kynance, and the valley of Downas with that of Meludjack, both near Coverack. In these two cases the larger valley contains the less Head. The St. Mawes Creek seems to contain very little Head, whereas the coast-line just to the east has a thick bank. The Froe Creek has Head on the north side, not on the south, which looks as if a southern aspect favoured the accumulation of Head. The Helford River has apparently very little Head. The River Cober must have been a big stream in those days, and we do not find much Head round the shores of the Loe Pool. Nor do we find any Raised Beaches there or round the shores of other similar pools—Swanpool near Falmouth, and Slapton Ley in Devonshire. If the sea had access to these estuaries in the Raised Beach period, we should expect to find Raised Beaches on their shores, near their mouths. As the Loe Bar shingle and the Slapton Beach are both gravels of considerable antiquity, it is probable that they formed bars of some sort, keeping out the sea in Raised Beach times; and that they were swept out by torrents in Glacial times, and subsequently returned to their present position, where they still have a tendency to move ever inwards and away from the breakers.

One other point should be noticed, the full

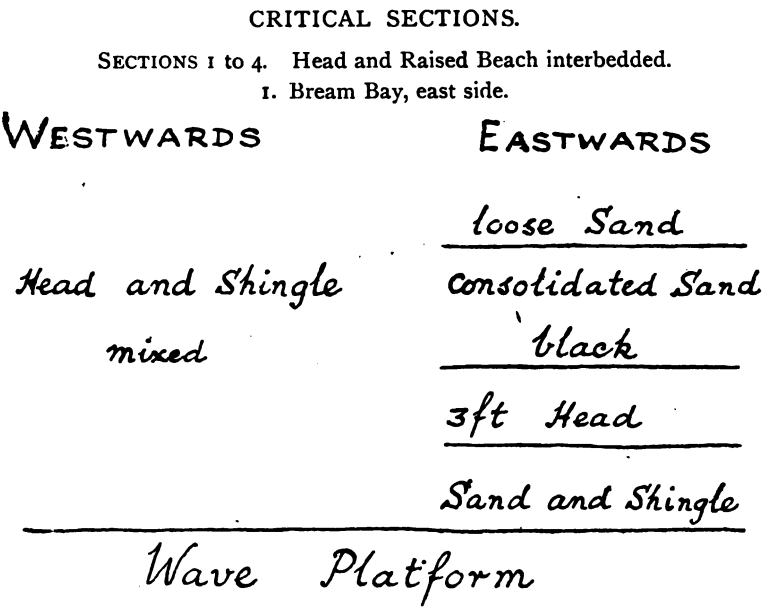
bearing of which I do not understand; submerged forests are found at the mouths of valleys.

Froe Creek, which was mentioned just now, deserves further notice. At some former time it undoubtedly was, as the *Survey Memoir* points out, joined to the sea at its top end, making St. Anthony's an island. The section fronting Towan Beach (No. 15) shows a cliff of Head, with an upper (A) and a lower (B) plateau, also an upper and a lower Raised Beach. Probably in Raised Beach times there was a channel through, and this is why the Raised Beach (lower) dies away in the middle of the bay. Then this channel became filled with Head. Then the sea partially cut a fresh channel through, eroding the Head to level B; the upper Raised Beach, which is only a patch, may have been deposited then; or it may be a case of interstratification of Head and Raised Beach. Then sand (C) blew up, choking the channel, and since that time the sea has encroached on the blown sand and Head, eroding a small cliff in its face.

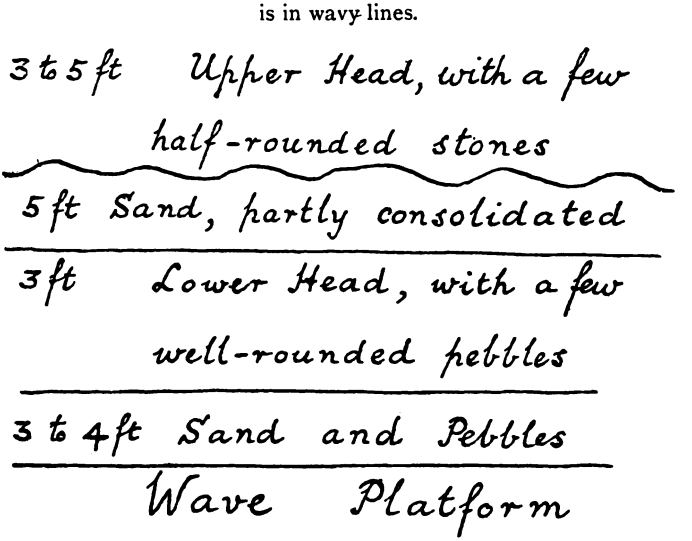
CRITICAL SECTIONS.

SECTIONS 1 to 4. Head and Raised Beach interbedded.

1. Bream Bay, east side.



2. Fistral Bay, near Sunny Corner. The Upper Head is in wavy lines.



3. Ternis Cove, near Marazion.

10 to 12 ft Fine Head
with a few stones

3 ft Beach and Head mixed

3 ft Fine Red Clayey Head

Boulders and Pebbles.

Wave Platform

4. Trebetherick, opposite to Padstow. All the layers are wavy, pockety, and interstratified.

Blown Sand, modern

1 to 2 ft Stony Head

6 in. Fine Head, with pebbles

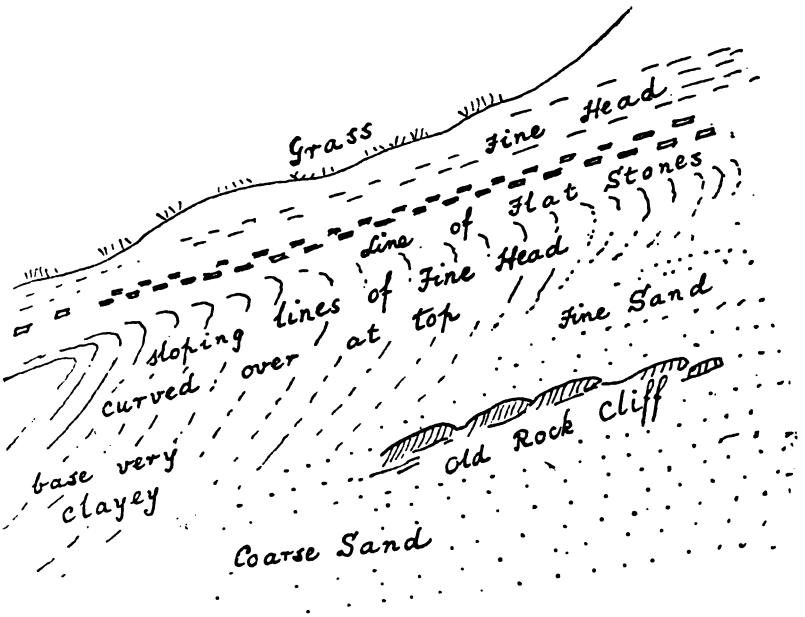
2 ft Stony Head

Thin Line of Sand, Stones & Pebbles

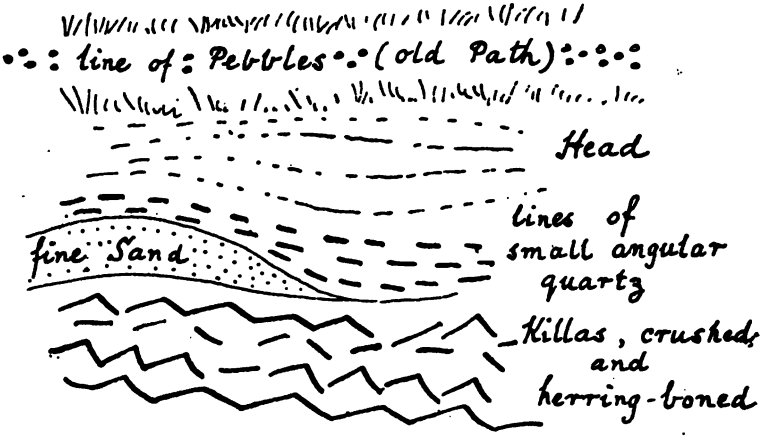
Wave Platform

SECTIONS 5 and 6. Head and Old Sand.

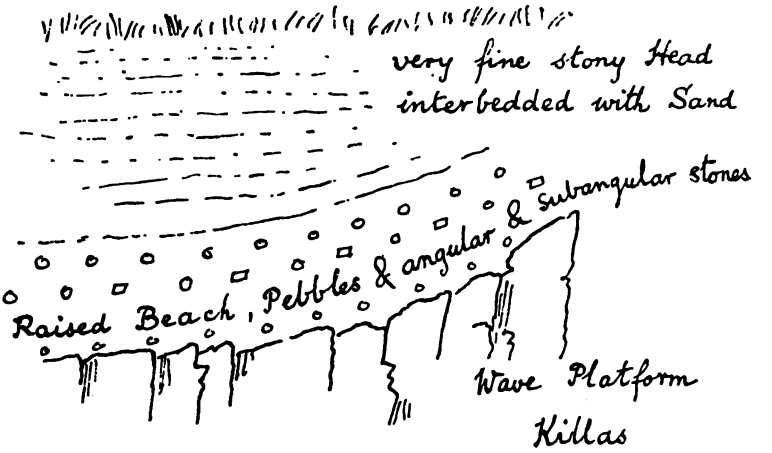
5. Quarry behind No. 1 Warehouse, Docks, Falmouth. The bank of Head has been cut into just at the foot of the steep slope above, i.e. just on the old cliff-line. The foot of the section is obscured by slips and rubbish, but, as shown in a pit near by, the Head passes down into fine washed gravel with pebbles, resting on a rock platform.



6a. Gyllyngvase, west side. Just at the seaward end of the granite foot-wall.

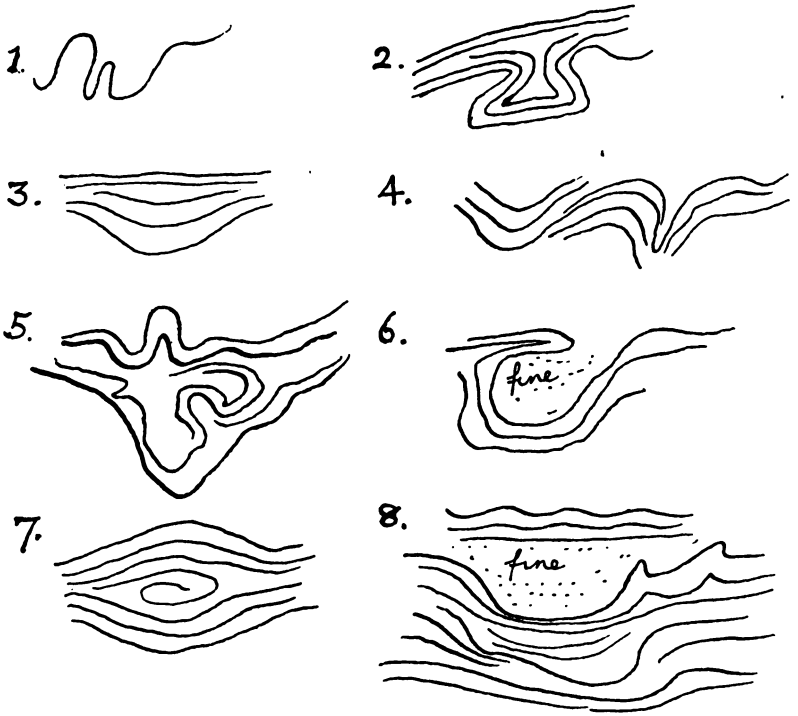


6b. Gyllyngvase. A little further west.

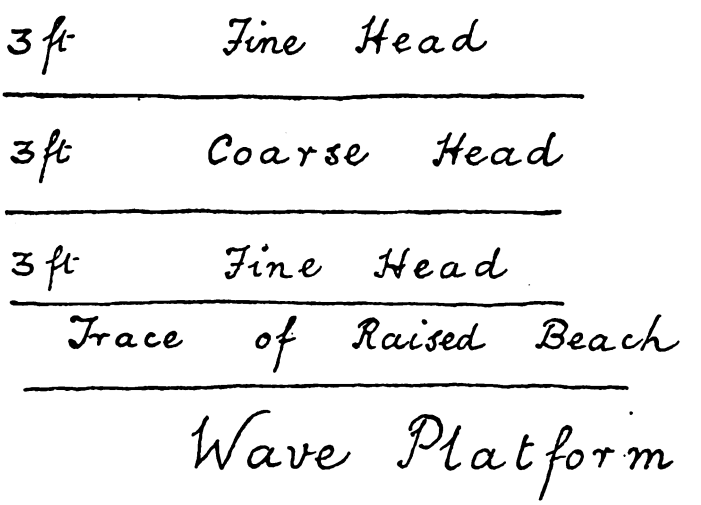


SECTIONS 7 to 11. Stratification of the Head.

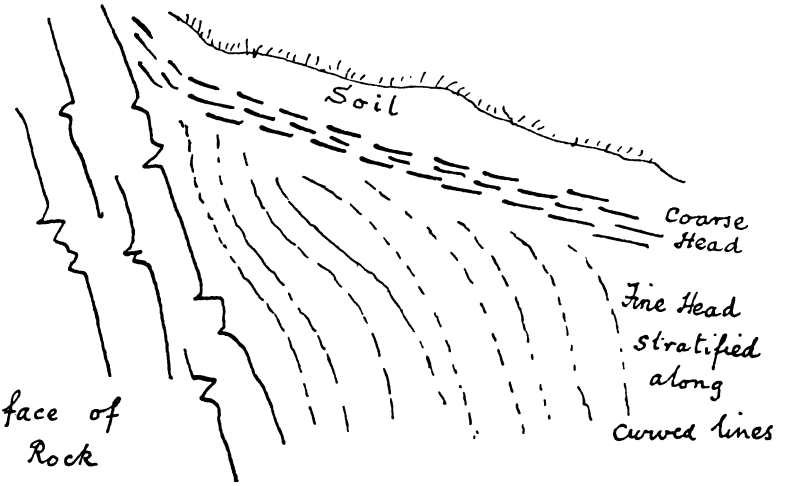
7. Downderry, contorted bedding of the Head. The lines are more or less stony.



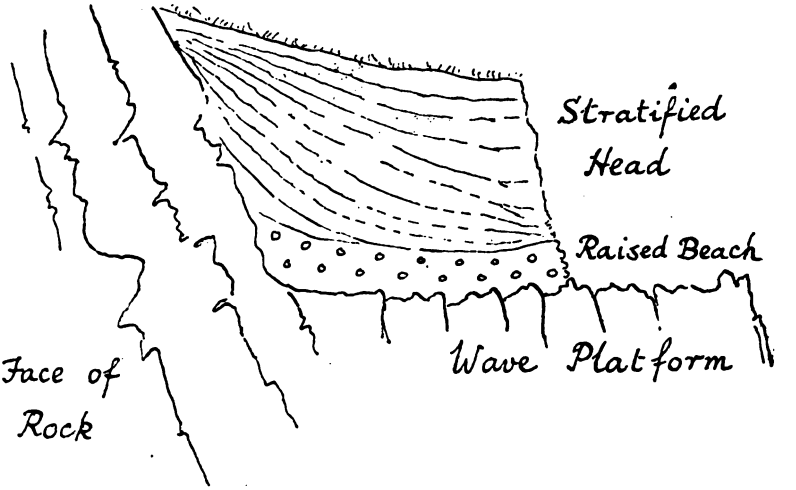
8. West of Durgan, Helford River.



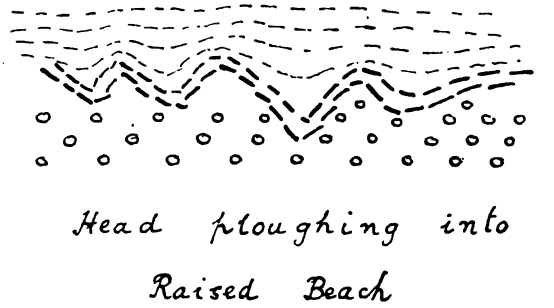
9. Near Grebe Point, Portscatho.



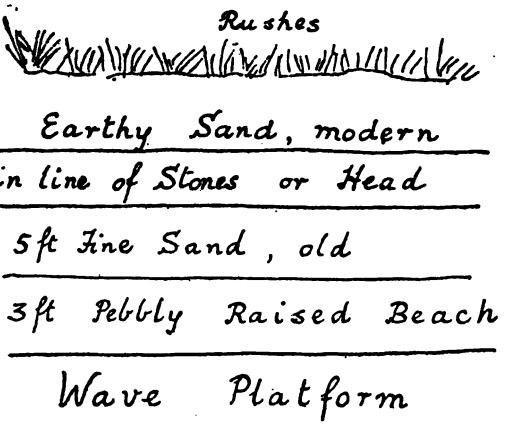
10. North end of Nelly's Cove, Porthallow.



11. North Centre of Towan Beach, St. Anthony in Roseland.



12. Strap Rocks, Gwithian, south of the Red River. Old and Modern Sand, separated by a thin line of Head.



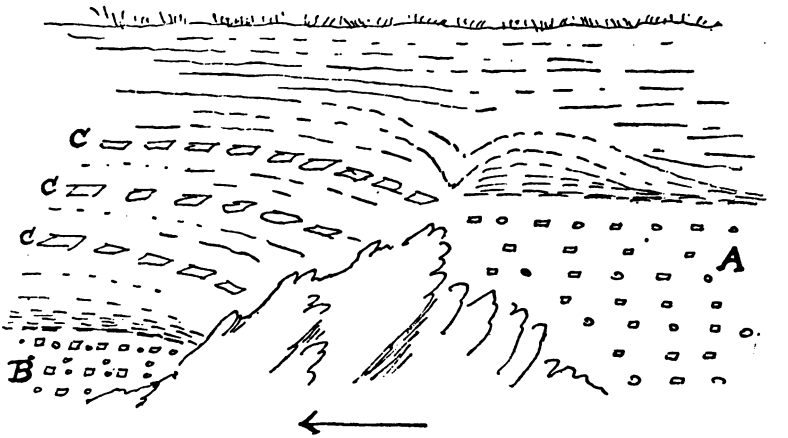
SECTIONS 13 and 14. Movement of Head, crushing the edges of upturned strata of Killas.

13. Penarrow Point, near Mylor.

A. Washed Head, with pebbles—three feet.

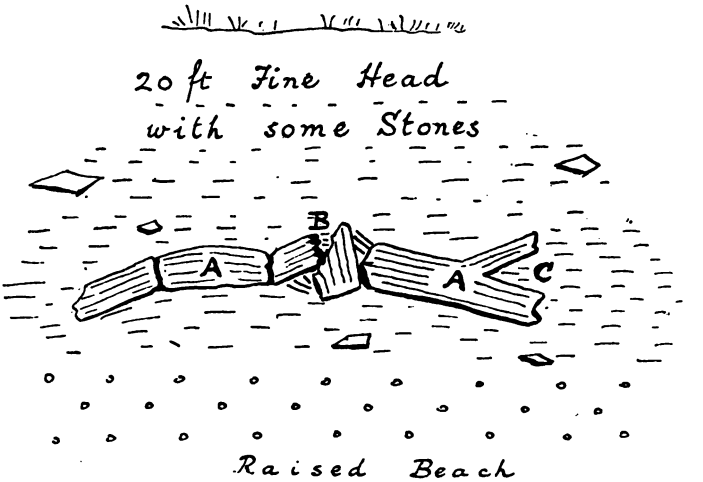
B. Washed Head, with pebbles—one foot, lying under the lee of the rock.

C.C. Crushed edges of strata, carried with the Head.

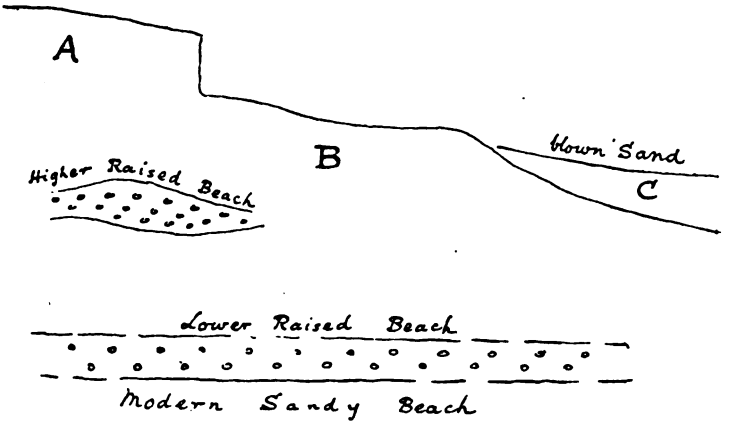


14. Pendower.

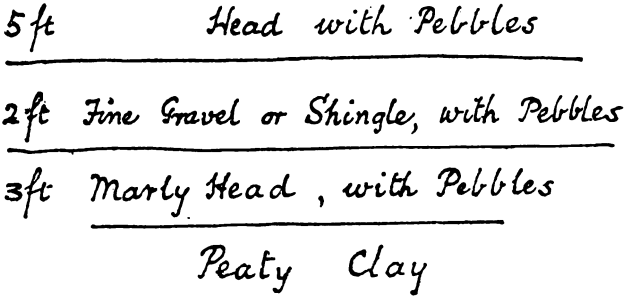
A. This, at first sight, looks like solid rock above the Raised Beach. But it is apparently a large flat slab of stone, which has been pushed forward in the Head, and broken into a zigzag fold (B); and the front end (C) has been opened out like a snake's jaws. In the Head above, there is a much larger piece of rock, which is also probably detached.



15. Towan Beach, St. Anthony in Roseland, south centre of Beach. Two levels of Head, showing old sea-channel, joining the head of Froe Creek to the sea. There are a few pebbles in the Head, at both levels, A and B.



16. Curious section at Millendreath (Looe), underneath the road. The peaty clay is apparently the same stratum as that which contains the Submerged Forest on the foreshore: and it looks as if the Raised Beach overlies the Forest Stratum. Perhaps it is not an ancient Pleistocene Raised Beach, but a recent beach, covered with recent Head and recently eroded.



ADDENDA TO THE WORKING LIST OF CORNISH PALÆOZOIC FOSSILS.

By J. H. Collins, F.G.S.

Eighteen years ago my "Working List of Cornish Fossils" was presented at the Annual Meeting of this Society, and was subsequently printed in the *Transactions*.* For ten years or more previous to that time scarcely any references had been made to the fossils of our Palæozoic rocks at any of our meetings, although attention had been drawn, by Mr. Fortescue Millet and others, to the then newly discovered fossils of the Pliocene beds at St. Erth. My list, therefore, was warmly welcomed as a useful summary of what had already been discovered and recorded, and it has greatly stimulated further research in the realm of Cornish Palæontology. It included references to about 250 distinct organisms which had been more or less particularly defined; of these the great majority, all, in fact, except about a dozen species of plants, are of marine origin and mostly deep-sea forms. "Thus there are nearly seventy brachiopods, at least thirty cephalopods, and several fishes represented in the Cornish

* Vol. XI, pp. 421–79.

Palæozoic fauna besides a considerable number of crinoids, corals, and sponges."* I remarked, "it is perhaps not unreasonable to expect that by placing this compendium of the work already done in the hands of local students many of them may be induced to search the cliffs and quarries more diligently than hitherto . . . here are fields of labour for many naturalists, and it is greatly to be desired that labourers may be forthcoming to occupy them.† My anticipations have been fulfilled to a very considerable extent, though mostly by veterans and not young students. In particular, the remarkable success of Mr. Howard Fox, Mr. Upfield Green, and others in fossil-hunting, and the cabinet labours of Messrs. Smith-Woodward, Gregory, Bather, Crick, Hinde, and others, have added largely to our knowledge of the fauna of our Palæozoic rocks, as the following addenda will fully demonstrate. I now proceed to note the principal discoveries of the past eighteen years under the following heads—corresponding nearly to those employed in the Working List, viz. :—

1. Protozoans.
2. Corals, Sponges, etc.
3. Brachiopods.
4. Molluscs.
5. Echinoderms.
6. Crustaceans.
7. Fishes.
8. Plants.

* *Ibid.*, p. 427. † *Ibid.*, p. 428.

In each of these groups the forms will be referred to alphabetically, references being added in most cases to illustrations and more detailed descriptions, and, as far as possible, to those contained in our *Transactions* and to specimens displayed in our *Museum.*

I must add, that with the exception of the coralline genus Petraia (formerly Turbinolopsis) no attempt has been made at Palæontological revision, nor even at a revision of the nomenclature employed at different times by the various authors.

The following abbreviations are employed :—

Trans. R.G.S.C. Transactions of the Royal Geological Society of Cornwall.

W.L. Working List of Cornish Palæontological Fossils, 1892.

Trans. Dev. Assoc. Transactions of the Devonshire Association.

Q.J.G.S. Quarterly Journal of the Geological Society of London.

Geol. of Bod. Memoirs of the Geological Survey. Geology of Bodmin and St. Austell, 1909.

Geol. of Mev. Ibid., 1907.

Geol. of Newquay. Ibid., 1906.

Geol. of Plymouth. Ibid., 1907.

Pal. Foss. Phillips's Palæozoic Fossils of Cornwall, etc., 1841.

Pal. Soc. Palæontological Society.

Dev. Fauna. Whidborne's Devonian Fauna of the S. of England.

B.M. British Museum.

P.M. Penzance Museum.

T.M. Truro Museum.

M.P.G. Museum of Practical Geology, Jermyn St.

G.S. Coll. Collection of the Geological Surveys of Great Britain.

I. PROTOZOANS.

(a) Foramenifera.

Several species have been met with in the Cornish rocks, near Halton Quay and other places, of the genera *Endothyra*, *Prochammina*, *Dentalium*, and *Nodosinella*. See Hinde and Fox, *Trans. Dev. Assoc.*, 1896.

(b) Radiolaria.

Mr. Howard Fox's discoveries of Radiolaria in the pre-silurian cherts of Mullion Island, St. Keverne and Gorran, and in the lower culm measures between Boscastle and the Tamar, were made known at the meeting of this Society in November, 1895, and at subsequent meetings. Some of the forms met with were beautifully sketched by Miss Gulielma Lister and Mr. A. T. Hollick, and named by Dr. Hinde. The following species have been definitely distinguished, figured, and named.*

Amphibrachium, *a* (Haeckel), Carzantic Quarry. See *Q.J.G.S.*, 51, Pl. XXVII, fig. 7.

* See *Trans. R.G.S.C.*, Vol. XII, p. 39 *et seq.*, and the accompanying plates (1896), also p. 278 and plates (1899); also *Q.J.G.S.*, Vol. 51, pp. 609–68, with plates (1895), and Vol. 55, pp. 214–19 and plates (1899).

Amphibrachium, β (Haeckel), Carzantic. *Ibid.*, fig. 5.

Carposphæra nana (Hinde), Mullion Island, Chypons. See *Q.J.G.S.*, 55, p. 215, and Pl. XVI, fig. 2.

Cenellipsis setosa (Hinde), Chypons. *Ibid.*, fig. 7.

Cenellipsis favosa (Hinde), Mullion Island, Chypons. *Ibid.*, fig. 8.

Cenellipsis scitula (Hinde), Chypons. *Ibid.*, fig. 6.

Cenellipsis, α (Hinde), Carzantic. *Ibid.*, Pl. XXVI, fig. 1.

Cenosphæra, sp. (Ehrenberg), Mullion Island, also at St. Columb Porth, in pebbles of unknown origin. See *Trans. R.G.S.C.*, Vol. XII, pp. 66-70, figs. 1, 2, 3, 11, 17.

Dorysphæra, sp. (Hinde), St. Columb Porth, in pebbles of unknown origin. *Ibid.*, figs. 8, 9, 13.

Druppula, β (Haeckel), Carzantic. *Q.J.G.S.*, 51, Pl. XXVI, fig. 7.

Druppalonche clavigera (Hinde), Chypons. *Ibid.*, 55, Pl. XVI, fig. 14.

Druppalonche ovata (Hinde), Chypons. *Ibid.*, fig. 15.

Ellipsoxiphus, sp. (Dunck.), Tregeare Down. *Ibid.*, 51, Pl. XXVI, fig. 10.

Sethocapsa, α (Haeckel), Carzantic. *Ibid.*, Pl. XXVII, fig. 17.

Sphærozoum, sp. (Meyen), Carzantic, Trenute, St. Dominic. *Ibid.*, 51, Pl. XXV, figs. 1*a*–1*g*.

Staurodruppa nucula (Hinde). *Trans. R.G.S.C.* XII, p. 278, figs. 1, 2.

Staurodruppa Foxii (Hinde), Chypons. *Q.J.G.S.* 55, Pl. XVI, figs. 11, 12, 13.

Stigmosphæra echinata (Hinde), Chypons. *Ibid.*, 55, Pl. XVI, fig. 1.

Stigmosphærostylus inæqualis (Hinde), Chypons. *Ibid.*, fig. 3.

Theodiscus, sp. (Haeckel), St. Columb Porth, in pebbles of unknown origin. *Trans. R.G.S.C.*, XII, figs. 14, 15, 16.

Trochodiscus (?) dubius (Hinde), Chypons. *Q.J.G.S.*, 55, Pl. XVI, figs. 4, 5.

Xiphostylus, sp. (Haeckel), Trekenner Head and Trenute. See *Trans. Dev. Assoc.*, July, 1896.

The species of Radiolaria hitherto met with only in the culm measures of Cornwall proper, *viz.* Amphibrachium α, Amphibrachium β, Cenellipsis α, Druppula β, Ellipsoxiphus, and Sethocapsa α, will probably be found by further search in the numerous Devon localities, while the following species hitherto met with only in Devon may reasonably be expected to appear in the Cornish localities, viz.:—Acanthosphæra laxa, Carposphæra, α, β, γ, δ; Cenosphæra, α, β; Druppula, α; Lithocyclia, Lithostrobus, Porodiscus lens, P. brevis, P. percinctus, P. clathratum, α; Rhopalastrum ingens, R. clavatum, R. α; Sethodiscus Chudleighensis, Staurolonche, α; Stylosphæra, α; Stichocapsa, α; Thecosphæra, α; Thecodiscus aculeatus, Trigonocyclia, α, β; Xiphosphæra, α, β; Xiphostylus, α, β, γ.

2. CORALS, SPONGES, ETC.

Alveolites (Millepora, Aulopora, etc.) repens, A. Labechei, A. vermicularis, A. similis. See W.L.

Alveolites, sp. See spec., P.M., 1688 from Bedruthan and 1839 from Cant Hill.

Amplexus tortuosus. See W.L. and specs. 35, 36, from near Yealmbridge.

Amplexus, sp. See spec. 1796 from Cant Hill.

Berenicia McCoyii. See W.L. and spec. 919.

Caunopora ramosa. See W.L. and specs. 825, 1455, 1459.

Cladochonus. See W.L. and specs. 1477 from S. Petherwyn, 42 from Delabole, 37 from Yealmbridge, 1015 from the Van, and 928 to 933, also 1476, from the Blackhead, reported also from Cant Hill by H. Fox. See *Trans. R.G.S.C.*, XIII, p. 123, and Pl. A, figs. 6*a*, 6*b*.

Cyathophyllum binum, C. Bucklandi and C. cæspitosum. See W.L.

Cyathophyllum celticum, C. elongatum, C. pauciradialis, C. pluriradialis, etc. See Petraia.

Cystiphyllum siluriense. See W.L. and spec. 572.

Discophora. See W.L.

Favosites cervicornis, F. cristata, F. fibrosa, F. Gothlandica, F. polymorpha, etc. See W.L. and many specimens in the Museum.

Fenestella antiqua, F. arthritica, F. laxa, F. plebeia. See W.L. and specs. 28, 29, 30, 50, etc.

Fenestella assimilis (Lonsdale). Found by

Messrs. Green and Sherborn at Porthluney. See *Geol. Mag.*, January, 1906.

Fenestella, sp. Found by Mr. H. Fox at Cant Hill. See specs. 1808, 1820, 1822, etc.

Fistulipora, sp. Found by Mr. H. Fox at Cant Hill and Bedruthan. See spec. 1735.

Glauconome bipinnata. See W.L. and specs. 26, 27, 1905, from S. Petherwyn.

Glauconome, sp. See specs. 1478, 1479 from S. Petherwyn.

Gorgonia. See Polypora.

Graptolites. See W.L. But there is no reason to believe that any true graptolites have been found as yet in Cornwall.

Heliolites (?), sp. Found at Creggars rocks. See *Geol. of Newquay*, p. 15.

Heliophyllum Hallii. See W.L. and spec. 365 from Pridmouth.

Lindstrœmia (Nicholson). No coral belonging to this genus has been found as yet in Cornwall, but spec. 2152 from Crownall Bay, which is just on the border of the county, has been identified by Professor J. W. Gregory.

Lodanella mira (Kayser). This is a sponge (some say, however, a cystid) of Lower Coblenzian age. Found at Porthluney and Polyne by Messrs. Green and Sherborn. See *Geol. Mag.*, Vol. III, p. 552; a specimen (B.M.P., 7967), in the British Museum.

Lophophyllum? See spec. 1643 from Bedruthan; compare also spec. 421.

Michelinia, sp. See spec. 1617 from Bedruthan, 1618 from Porthmear, 1619, Portcothan, 1620, Lower Butter Cove—the first three found and presented by Mr. H. Fox, the fourth by Mr. Rupert Vallentine.

Microcyclas simplex (Sandb.), specs. 974–975, N. Constantine Bay; 1519–1622, Bedruthan.

Millepora, sp. Found at Porthluney by Messrs. Green and Sherborn. See *Geol. Mag.*, June, 1906.

Monticulipora (Monotrypa), sp. Found at Cant Hill and Bedruthan by Mr. H. Fox. See specs. 1651, 1732, 1767. Also a Monticuliporoid "ramifying through the whole mass of the lenticle (of limestone), found by Messrs. Green and Sherborn at Porthluney. See *Geol. Mag.*, January, 1906.

Nerites? See W.L.

Pachypora reticulata, Bedruthan.

Petraia (includes Cyathophyllum in part). The following species have been investigated and distinguished by the present writer (see his papers in *Trans. R.G.S.C.*, XI, pp. 553–557 and 645–654):—

P. celtica (Milne-Edwards). See specs. 213, 102, 187, 189, etc.

P. gigas (McCoy). See specs. 104, 105, 244, 267, etc.

P. pluriradialis (Phillips), specs. 247, 282, 292, etc.

P. elongata (Milne-Edwards), specs. 108, 109, 249, 389, 461, etc.

P. pauciradialis (Phillips), specs. 103, 377, 1608, etc.

P. minimus (Couch), specs. 387, 388.

P. Trelawniensis (Couch), specs. 110, 218, 243, etc.

To the above may be added:—

P. radiata (Muenster), found at Polyne by Messrs.

Green and Sherborn (*Brit. Mus.*, R. 7496, 7561), and P. punctocrenulata (Roemer), (*Brit. Mus.*, R. 6978). See also spec. 1813 in the Penzance Museum from Cant Hill, presented by Mr. H. Fox.

P. subduplicata (McCoy) is probably a Lindstroemia.

Phillipastræa (Astræa, Smithia) Hennahi. Found at Dinas Head by Mr. H. Fox, polished spec. P.M. No. 1911. See *Pal. Foss.*, Pl. VI, fig. 16.

Phyllopora sp., Cant Hill, spec. 1821. Found and presented by Mr. H. Fox.

Pleurodictyum problematicum. See W.L.; of this coral there are many specimens in our Museum. Spec. 1737 is a wax cast of a pretty specimen (original in *Brit. Mus.*) found by Mr. H. Fox and figured *Trans. R.G.S.C.* XII, pl. 16. See also spec. 1864 from St. Minver, 1805 and 1865 from Cant Hill, and 1812 from East of Porthilly quarry. Compare also Peach's specimen 1738 from East Looe. The same coral was found by Mr. Green in the Polyne Quarry; specimens now in the British Museum (R. 6072 and R. 6973). See *Geol. Mag.*, January, 1906.

Polypora sp., *cf.* Polypora or Gorgonia ripisteria of Phill. *Pal. Foss.*, Pl. XI, figs. 30–33. See also spec. 1761 from Bedruthan, found and presented by Mr. H. Fox.

Protovirgularia dichotoma. See W.L.

Ptilodictya. See W.L. P. lanceolata (Lonsd.), found by Messrs. Green and Sherborn at Porthluney. See *Geol. Mag.*, January, 1906. See also

spec. 1601 from Gunwallo Cove; 1602, south of Pengwinion, and 1603, Tangye Ryn, found and presented by Mr. H. Fox.

Receptaculites. See W.L.; a specimen found by Mr. Green in the quarry west of Looe River has been presented to the British Museum.

Retepora infundibula. See W.L. and P.M. 826, 827, 828.

Rhipidophyllum? See spec. 101 (P.?).

Sabellaria alveolata. See W.L.

Scolithus. See W.L.

Serpulites longissimus (J. de C. Sowerby), found by Mr. Sherborn in Fletching's Cove. See *Geol. Mag.*, July, 1904.

Sphæronites (Sphærospongia) tesselatus. See W.L.

Stromatopora sp., found at Rope Haven by Messrs. Green and Sherborn, and presented to the British Museum.

Strombodes vermicularis (Cyathophyllum cæspitosum). See spec. 179.

Worm-tracks. See W.L.

Zaphrentis sp. Found at Newquay. See *Geol. of Newquay*, p, 13.

Several new Zaphrentoid corals found in the rocks of Devon have been figured and described by Mr. A. Champernowne (see *Q.J.G.S.*, August, 1884); some of the figures have a rude resemblance to the much more elegant and apparently more highly organized Cornish Petraias.

3. BRACHIOPODS.

Much good work has been done on these since the publication of Davidson's great work, and this has particularly affected the nomenclature. There is, however, good authority for the names here adopted, although they need much revision, and it is quite possible that some of the specimens are wrongly referred owing to their imperfections—many being merely fragmentary and distorted casts.

Amphicœlia striata (Sow.). Found at Porthluney. See Green and Sherborn, *Geol. Mag.*, January, 1906.

Athyris (Atrypa) concentrica (Von Buch), A. hispida, A. indentata. See W.L. Found at S. Petherwyn and Padstow, also at Lummaton, in Devon.

Athyris = (Spirigera or Cleiothyris) Royssii (Léveillé and Whidborne). Found at S. Petherwyn, as also in Devon. See Whidborne, *Dev. Fauna*, Vol. III, part II, Pl. XVII, fig. 13; XVIII, figs. 1–5, and XX, figs. 1–2. See also specimen in M.P.G. $\frac{34}{28}$.

Athyris plebeia. See Merista plebeia.

Athyris undata (Def.) Reported from Polyne by Mr. Upfield Green. See *Geol. Mag.*, August, 1904; and January, 1906, *ibid.* See specs. 1712, 1713 from West Looe, 1510, 1514 from Fowey, 1585. Compare also 1125 from Fowey with Athyris undata, var. aviceps (Kayser).

Atrypa desquamata. See W.L. and spec. 1802 from Cant Hill.

Atrypa reticularis (Linné) and *var.* aspera (Schlotheim). See W.L. and spec. 1782 from Cant Hill, presented by Mr. H. Fox, also 1330 from Polruan, and 1328 from Pridmouth.

Camarophoria rhomboidea. See W.L.

Camarotœchia laticosta. See spec. 1834 from Cant Hill, presented by Mr. H. Fox.

Centronella (Cryptonella). Found by Mr. Fox at Trevone and Mother Ivey's Bay. See specs. 1613, 893. Compare C. virgo, *Pal. Soc.*, 1893, Pl. XI, figs. 4, 6.

Chonetes hardrensis = Orthis hardrensis. See W.L.

Chonetes minuta (plebeia). Found at Archer's Quarry, near Launceston, by Mr. H. Fox, specs. 1535, 1538. See *Trans. R.G.S.C.* XII.

Chonetes sp. Bedruthan. See spec. 1762.

Gypidula. See Pentamerus.

Leptæna laxispina, (Phill.) = Strophalosia productoides. (Davids.) Petherwyn.

Leptæna (strophomena) laticosta. West Looe. See W.L. and spec. 641, 773.

Leptæna Looiensis. See W.L.

Leptæna scissa, Catasuent Cove. See *Geol. of Newquay*, p. 21.

Lingula squamiformis. See W.L.

Merista (athyris) plebeia. Reported from Padstow and near Launceston. Figured by Whidborne from Lummaton, *Dev. Fauna*, Vol. II, part III, Pl. XII, fig. 30b.

Meganteris? Archiaci? See spec. 1052 from E. Looe. Whidborne figures a specimen from

Lummaton (*Dev. Fauna*, Vol. II, part III, Plate XII) as M. inornata.

Orthis Actoniæ, O. alternata, O. arcuata, O. Berthosi, O. Budleyensis, O. calligramma, and O. canaliculata. See W.L. and specs. 1110, 1114, 1120, 661, 1113, 1115 from Gorran. Mr. Green has placed a specimen of O. calligramma from Porthluney, in the British Museum.

Orthis circularis (Sow.). See W.L. Found at Polyne and Looe by Messrs. Green and Sherborn. See *Geol. Mag.*, August, 1904, and January, 1906. Compare also specs. 1586 from Tintagel, 988 and 1506 (named O. hipparionyx) from Fowey.

Orthis compressa, O. confinis, O. elegantula, O. flabellulum, O. furcifer, O. hipparionyx, O. interlineata, O. lunata, and O. pecten. See W.L.

Orthis muschicura. See O. personata.

Orthis personata (Zeill.) = O. hipparionyx (Vanuxem) in part = O. provulvaria (Maurer) = O. Vulvaria (Schloth.) = O. hysterita = O. muschicura (Beclard) = Schizophoria (not the O. hipparionyx of Hall). Mr. U. Green reports from Looe (Polyne) in *Geol. Mag.*, August, 1904, and January, 1906. Reported also from Polperro and Tintagel. See specs. 1707, 1708, 1604, 1048, 1140, etc., and *Geol. of Plymouth*, p. 32.

Orthis piligera? S. Petherwyn. See spec. 1591.

Orthis plicata. See W.L.

Orthis porcata? Found in the Peraver Quarry. See *Geol. of Mevagissey*, p. 35.

Orthis protensa, O. radians, O. resupinata, O.

retrorsistria, O. striatula, O. testudinaria, O. vespertilio. See W.L.

Orthis sp. Found in Ladock Quarry (?), specimen in Truro Museum, cast in M.P.G. $\frac{29}{25a}$. See *Geol. of Newquay*, p. 35.

Orthonota sp. Red Cove, Bedruthan. See M.P.G. $\frac{30}{17a}$.

Orthotetes crenistria (Phillips), *var.* Arachnoidea = Orthis semicircularis (Phillips) = Spirifer arachnoidea (Phillips) = Streptorhynchus crenistria (Davidson) = Orthotetes crenistria (Whidborne). S. Petherwyn, etc. Found also at Cant Hill by Mr. H. Fox, spec. 1809. See also *Geol. Mag.*, April, 1905, p. 149.

Orthotetes hipparionyx (Vanux.) = Orthis personata. Found behind the Gasworks at Looe. See *Geol. of Plymouth*, p. 32.

Orthotetes Sedgwickii = O. Murchisonii. Tintagel, spec. 1592.

Orthotetes umbraculum. Found at Tintagel, Fowey, etc. See specs. 1511, 1586, 1589, 1598.

Pentamerus (Gypidula) brevirostris (Phill.). Found at Cant Hill by Mr. H. Fox. See spec. 1845.

Productus subaculeatus. See W.L. and spec. 980 from S. Petherwyn.

Rensellaria (?) strigiceps (Roemer). Found at Polyne by Mr. Green. See *Geol. Mag.*, August, 1904, and January, 1906.

Rensellaria (?) ornata. Fowey. Internal cast. See spec. 1203.

Retzia longirostris (Kayser). Found at Mother Ivey's Bay by Mr. Fox. See spec. 1772, and *Trans. R.G.S.C.*, XII, p. 754.

Rhynchonella acuminata, R. anisodonta. See W.L.

Rhynchonella laticosta. See Camarotœchia laticosta.

Rhynchonella livonica (von Buch) = R. daleidensis. Found at Polyne by Mr. Green. See *Geol. Mag.*, 1904. Spec. 1810 from West Looe.

Rhynchonella Pengelliana. See W.L.; also specs. 488, 792, 876, 877, 884, 1054, 1503.

Rhynchonella (Camarotœchia) pleurodon = R. Partridgiæ of Whidborne; R. pugnus, R. reniformis. See W.L.

Rhynchonella Stricklandi. See *Trans. R.G.S.C.*, XII, p. 239, and spec. 1515 from Fowey.

Rhynchonella subdentata. See W.L.

Rhynchotreta cuneata (Dalen). Found at Porthluney by Green and Sherborn. See *Geol. Mag.*, January, 1908.

Spirifer Arduenensis (Schnurr). Found by Mr. Green at Fowey. Specimen in Truro Museum.

Spirifer Barumensis. See W.L.

Spirifer costata. See W.L. Reported also from Pridmouth, Polruan, Lantic Bay, etc. See specs. 1228, 1229, 1230, 1239, 1243, etc.

Spirifer cultrijugatus (part). See sp. primævus.

Spirifer curvata. See W.L.

Spirifer daleidensis (Stein). Includes Davidson's sp. curvata and S. undulata (not Schlotheims).

Spirifer hysterica (Schloth). See W.L. Includes sp. Mercurii (Gosselet). See specs. 836, 1509, from Fowey. Reported also from Looe by Mr.

Green. See *Geol. Mag.*, July and August, 1904. Also reported from Padstow.

Spirifer lævicosta (Vanux) *Geol. of Plym.*, p. 40. See W.L.

Spirifer mesomala, S. obliterata. See W.L.

Spirifer lineata from S. Petherwyn. Specimen in the Exeter Museum.

Spirifer pinnatus (Attwater). See W.L. and spec. 38 from Tintagel.

Spirifer primævus (Stein). See W.L. and spec. 1099 from Polruan, 1526 from Pridmouth, 1847 from Cant Hill, and 1874 from St. Veep. Mr. Green has found this species at Polyne (see *Geol. Mag.*, January, 1906), and has placed a specimen in the Truro Museum.

Spirifer solitarius (Krantz). Found by Mr. Green at Fowey, spec. in M.P.G.

Spirifer speciosa. See W.L. Compare spec. 1846 from Cant Hill, also 1512, 1521, 1522 from Fowey. No. 682 from St. Veep is also referred here by Mr. Whidborne, and 1872 from the same place by Mr. R. Etheridge.

Spirifer striata. See W.L. This species is fairly common in the Pilton and Marwood beds of N. Devon according to Whidborne, who adopts the name of Spirifer microgemma. Cornish specimens are doubtful.

Spirifer subcuspidatus (Schnurr). See spec. 1583 from Tintagel, 852*a* from Pridmouth. Found at Polyne by Messrs. Green and Sherborn. See *Geol. Mag.*, January, 1906.

Spirifer Trigeri? Tintagel, spec. 1587.

Spirifer trigonalis. See W.L.

Spirifer unguiculus (Sow.). Peth., spec. $\frac{34}{42}$ M.P.G.

Spirifer Urii. See W.L. Spec. 791 from S. Petherwyn (with Thecidium ?) named by Mr. Whidborne. A good specimen in the Exeter Museum.

Spirifer Verneuilli. See W.L. Specs. 43, 44, etc.

Spiriferina cristata (Schloth.). See W.L.

Streptorhynchus (Strophodonta) crenistria. See W.L.

Streptorhynchus (Strophodonta) gigas. See W.L. and spec. 577. Mr. Green found it at Looe and Polyne. See *Geol. Mag.*, August, 1904, and January, 1906, also *Geol. of Plym.*, p. 33, spec. in Truro Museum.

Streptorhynchus persarmentosus. See W.L.

Streptorhynchus (Orthotetes) umbraculum. See W.L.; also specs. 907, 965.

Stringocephalus Burtini. See W.L.

Strophalosia productoides. See W.L. and specs. 80, 81, 380, 795, 1552.

Strophomena applanata (Salter). See W.L.

Strophomena explanata. Reported by Mr. Green from Looe. See *Geol. Mag.*, August, 1904.

Strophomena grandis. See W.L. and specs. 854, 855.

Strophomena Murchisoni. Mr. Green reports its occurrence at Looe. See *Geol. Mag.*, August, 1904. Compare also spec. 67.

Strophomena pecten. See W.L.

Strophomena piligera. See spec. 1662 from Bedruthan.

Strophomena plicata, S. protensa, S. rhomboidalis, S. sordida. See W.L.

Thecidium? sp. S. Petherwyn. See spec. 791.

Uncinulatus sub-Wilsoni (Rhynchonella pila) from Tintagel. See spec. 1559.

4. MOLLUSCS.

(*a*) LAMELLIBRANCHS (bivalves). These are comparatively rare in the Cornish Palæozoic rocks.

Actinodesma obsoletum. See Pterinea lamellosa.

Allorisma concinna (Thomas). Portquin, with Buchiola retrostriata. See Thomas, *Geol. Mag.*, p. 97, and Pl. III, 1909, and Geol. Surv. Coll., 23078.

Avicula (Ptychopteria) damnoniensis. See W. L. and spec. 1122 from S. Petherwyn, 1234 from Fowey, etc.

Avicula exarata, A. subradiata, Aviculopecten arachnoides, A. alternata. See W.L.

Aviculopecten granulosus. Landlake. See W.L. and M.P.G. $\frac{35}{7}$.

Aviculopecten pectinoides (McCoy). See spec. 1262 from Fowey.

Aviculopecten plicatus. See spec. 181 from S. Petherwyn.

Aviculopecten radiata (Goldf.). See spec. 617 from Looe.

Aviculopecten transversus. See W.L. and spec. 1236 from S. Petherwyn, 1294 from Punch's Cross.

Buchiola retrostriata (von Buch), Portquin, with Allorisma concinna.

Cardiola retrostriata (Keys) (Cardium palmatum). See W.L. Found also at Trevone by Mr. H. Fox. See specs. 293, 903, 1803, 1804; also *Geol. Mag.*, April, 1905, p. 150, and *Geol. of Plym.*, pp. 74–80.

Conocardium, sp. Looe and Fowey. See Green, *Geol. Mag.*, August, 1904.

Ctenodonta antiqua and Ct. elliptica. See W.L.

Ctenodonta, sp. Fowey. See M.P.G. $\frac{39}{17}$ and $\frac{28}{14}$.

Cucullea, sp. See W.L. and specs. 1202, 1210, 1231, 1232.

Cypricardia (Myophoria) deltoidea, C. semi-sulcata. Peth. See W.L. and M.P.G. $\frac{35}{34}$.

Leptodomus semi-sulcata, Landlake. M.P.G. $\frac{35}{51}$.

Pecten granulosus (Phill.), Landlake. See M.P.G.

Pterinopecten Hallii (Whidb.) Petherwyn. See M.P.G. $\frac{35}{7}$ = Aviculopecten alternatus.

Modiola amygdalina. See W.L. and P.M. 1218, Punch's Cross, and 1227, Pridmouth.

Posidonomya Becheri; P. lateralis. See W.L.

Posidonomya venusta (Muenst.). Found at Rooke Mill Quarry, St. Kew, and at St. Germans Park. See *Trans. R.G.S.C.*, XIII, p. 134, and *Geol. of Plymouth*, p. 63.

Pterinea costata. See specs. 958, 1239, 1240, 1254, 1285, 1508, Fowey and Polruan.

Pterinea lamellosa = Actinodesma obsoletum. See specs. 1182, 1235, 1528.

Pterinea spinosa; P. ventricosa. See W.L.

Pterinea sub-radiata. (Peth.). M.P.G. $\frac{45}{6}$.

Ptychopteria. See Avicula (Ptychopteria) Damnoniensis.

Sanguinolaria elliptica. See W.L. and specs. 182, 184, 1545, etc.

Sanguinolaria sulcata. See W.L.

Schizodus deltoideus. See W.L.

(*b*) UNIVALVES (Gasteropods, Pteropods, Heteropods, etc.). These are still rarer than the bivalves in the Cornish rocks.

Antitrochus arietinus. See W.L.

Bellerophon bilobatus; B. hiulcus; B. Woodwardii. See W.L.

B. bisulcatus, Fowey, M.P.G., $\frac{30}{18}$ ($\frac{28}{18}$). See also *Geol. of Bod.*, p. 4.

Capulus compressus; C. tylotus. See W.L.

Capulus subquadratus (Frech.) = Onychia (Kochia) capuliformis (Sandb.). Found by Mr. Green at Looe. See *Geol. Mag.*, July and August, 1904.

Conularia complanata, sp. nov., Padstow? *Pal. Soc.* British Conulariæ, p. 35, and Pl. IV, figs. 12, 14. See spec. in Brit. Mus., 8229 c.

Conularia deflexicostata (?) (Sandb.). Found by Mr. H. Fox at Cant Hill and west of Gentle Jane. Spec. 1806.

Conularia quadrisulcata. See W.L. and specs. 901, 902.

Conularia subparallela (Sandb.), spec. 1793 from Cant Hill. See *Geol. Mag.*, April, 1905, p. 150.

Conularia, sp. Found at Constantine Bay.

Euomphalus serpens. See Philoxene serpens.

Euomphalus, sp. Found at Trevone by Mr. H. Fox.

Holopella Hennahiana. S. Peth. See P.M. spec. 149; compare also Whidb., *Dev. Fauna*, Vol. I, part III, Pl. XVIII, fig. 16, from Devon.

Hyolithes. See spec. 1649. Found by Mr. Fox in Mother Ivey's Bay.

Loxonema Cornubicus, sp. nov. (Longstaff). Found at South Petherwyn. See *Q.J.G.S.*, LXV, Pl. X, fig. 2, and spec. in M.P.G.

Loxonema lineata; L. nexile; L. sinuosa; L. tumida. See W.L. S. Petherwyn.

Loxonema, sp. St. Eval.

Murchisonia angulata; M. gracilis. See W.L.

Murchisonia, sp. Bedruthan Steps.

Natica nexicosta. See W.L.

Nereitopsis (Green). See Pteroconus.

Onychia (Kochia), capuliformis (Sandb.) = Capulus subquadratus.

Philoxena serpens. See W.L. and spec. 1768 from Booby's Bay. A good specimen in the Exeter Museum from S. Petherwyn.

Pleurotomaria antitorquata; P. aspera; P. Chudleighensis. See W.L. (P. aspera, M.P.G., Peth., $\frac{35}{36}$).

Pleurotomaria cancellata (Phill.). Looe. See W.L. and *Geol. of Plym.*, 40.

Pleurotomaria striata(?) (Goldf.). Found at Looe by Mr. Green. See *Geol. Mag.*, August, 1904.

Pteroconus (Nereitopsis) cornubicus (Green and Hinde). Fowey. See specs. 1609, 1580, 1590, 1597, and *Trans. R.G.S.C.*, XII, Pl. F; figs 1–4 also found at Looe by Mr. Green. See *Geol. Mag.*, August, 1904.

Pteroconus mirus (Hinde). Bedruthan, Samaritan Island, etc., spec. 1637, etc., and *Trans. R.G.S.C.*, XII, p. 352, and Pl. 16, figs. 1–4.

Pterinea subradiata, Mid-Dev.; Cornish spec. in Exeter Museum.

Styliola, sp. Found at Epphaven by Mr. H. Fox. See *Geol. Mag.*, April, 1905, p. 150. Spec. 1773 Epphaven, 1838 Porthilly, 1853 Porthilly Cove. Styliola is very abundant in many of the Upper Devonian slates of East Cornwall. See *Geol. of Plym.*, p. 81, etc.

Tentaculites grandis (Roemer). Found at Looe by Mr. Green. See *Geol. Mag.*, 1904.

Tentaculites lævis (Richter). Found at Booby's Bay by Mr. H. Fox. Spec. 1766.

Tentaculites ornatus. See W.L.

Tentaculites scalaria. See specimen from Polruan, P.M. 990.

Trochus helicides. See W.L.

Turritella, sp. See W.L.

Vermetus antitorquata. Peth. M.P.G. $\frac{35}{69}$. See Pleurotomaria antitorquata.

(*c*) CEPHALOPODS (Goniatites, Orthoceras, etc.).*

Actinoceras baccatum (H. Woodward). Found at Porthluney by Mr. Upfield Green. See *Geol. Mag.*, July, 1904, p. 289. Specimen in Brit. Mus.

* For the revision of the nomenclature of this group I am indebted to Mr. G. C. Crick, F.G.S., of the British Museum. No revision of the named specimens in the Penzance Museum has yet taken place.

Actinoceras Devonicans (Whidborne). See W.L. and spec. 173.

Agoniatites inconstans *v.* Goniatites inconstans.

Agoniatites transitorius (Phillips). See spec. 1028 from Trevone, presented by Mr. Howard Fox.

Agoniatites, sp. from Cant Hill. See *Geol. Mag.*, April, 1905, and *Trans. R.G.S.C.*, XIII, Pl. I, figs. 2, 2a.

Agoniatites, sp. Ropehaven. Specimens given to B.M. (c. 10520, much pyritized) and M.P.G. by Mr. Upfield Green.

Anarcestes latiseptatus (Beyrich). See specs. 1029, 1031 from Trevone, and *Trans. R.G.S.C.*, XI, p. 638.

Anarcestes Nœggerathi (von Buch). See spec. 1035 from N. Constantine Bay, and *Trans. R.G.S.C.*, XI, p. 642.

Bactrites Budesheimensis (F. Roemer). See spec. 1034 from Trevone, and *Trans. R.G.S.C.*, XI, p. 637.

Bactrites, sp. Trevone. Spec. 821. See *Trans. R.G.S.C.*, Vol. XIII, p. 54, 1904.

Barrandeoceras holticum (Blake). See *Geol. Mag.*, July, 1904, p. 289. Found at Porthluney by Mr. Upfield Green. Spec. in the Brit. Mus.

Clymenia angustiseptata (? Muenster.) S. Petherwyn. Specimen in Brit. Mus., No. 37827.

Clymenia bisulcata ; C. lævigata ; C. linearis ; C. Münsteri ; C. Pattisonii ; C. plurisepta ; C. quadrifera. See W.L. and specs. 151, 170, 231, 232.

Clymenia sagittalis (Phillips) ? = C. angustiseptata

(Muenster) *fide* A. H. Foord. See W.L. and spec. 171.

Clymenia striata (Muenster). See W.L., also Brit. Mus., spec. 32956.

Clymenia subarmata (Muenster). S. Petherwyn. Specimen in the Exeter Museum. See also Goniatites insignis (Phillips).

Clymenia undulata (Muenster). See W.L. and Brit. Mus., spec. 32935, from S. Petherwyn.

Clymenia valida (Phillips). See W.L.

Cophinoceras, sp. See *Geol. Mag.*, 1905, p. 156, Pl. V, figs. 8a, 8b, and *Trans. R.G.S.C.*, XIII, Pl. I, figs. 8a, b.

Cyrtoceras nodosum (Phillips) ? Sphyradoceras (Whidborne, Holzapfel). See W.L.

Cyrtoceras rusticum (Phillips). See W.L.

Cyrtoceras, sp. Found at Pridmouth. Figured by G. C. Crick, *Trans. R.G.S.C.*, XII, p. 338, fig. 1, and spec. 936. Compare with C. depressum (Goldf.) and C. lineatum (Goldf.).

Glyphioceras crenistria *v.* Goniatites crenistria.

Glyphioceras spirale (Phillips), from Herod Down. See *Geol. of Plym.*, p. 104. A Lower Culm form.

Goniatites biferus (Phillips) = Maenaceras biferum. See W.L.

Goniatites crenistria (Phillips) = Glyphioceras crenistria (Phillips). See W.L.

Goniatites inconstans (Phillips) = Agoniatites inconstans (Phillips). See W.L.

Goniatites insignis (Phillips) = Clymenia subarmata (Muenster). See W.L. and spec. 172.

Goniatites linearis (Muenster) = Tornoceras lineare (Muenster).

Goniatites mixolobus (Phillips) = Prolecanites mixolobus (Phillips). See W.L.

Lituites (?) Specs. 219, 220, 266.

Maenaceras biferum *v.* Goniatites biferus.

Mimoceras compressus (Beyrich). Trevone, spec. 1036, and *Trans. R.G.S.C.*, XI, p. 638.

Nautilus megasipho (Phillips). See W.L.

Orthoceras Champernowni (Whidb.). See W.L.

Orthoceras cochleiferum (?) (Sandberger.) See *Trans. R.G.S.C.*, XI, p. 643.

Orthoceras commutatum (C. G. Giebel) = Orthoceras longicameratum (Foord) = Orthoceras Nassoviense (Foord). Found at Trewornan. See *Geol. Mag.*, April, 1905, p. 150, and spec. 1857.

Orthoceras, cf. commutatum (Giebel). Found at south of Dinham Cove by Mr. Howard Fox. See *Trans. R.G.S.C.*, XIII, p. 65, fig. 1, and spec. 1791.

O. cylindraceum (J. de C. Sowerby) = O. vennense (A. H. Foord) (spec. 679 from Punch's Cross). See W.L.

Orthoceras ellipticum (Pattison). S. Petherwyn Spec. 234.

Orthoceras encrinale and O. fusiforme (Salter). See W.L.

Orthoceras gracile (Blumenbach). Found at Trewornan. Specs. 1795, 1858. See *Geol. Mag.*, April, 1905, p. 150.

Orthoceras gracile (Phillips). See W.L.

Orthoceras, cf. hercynicum (Kayser). See

Trans. R.G.S.C., XIII, Pl. I, figs. 6*a*, *b*, and specs. 1790, 1862 from Cant Hill.

Orthoceras laterale (Phillips). See W.L.

Orthoceras longicameratum *v.* O. commutatum.

Orthoceras Nassoviense *v.* O. commutatum.

Orthoceras Oryx (Whidborne). See W.L.

Orthoceras, sp., cf. rapæforme (F. A. Roemer) and O. subconicum (Roemer). Found E. of Dinham Cove. See *Geol. Mag.*, April, 1905, p. 150, and spec. 1792.

Orthoceras speciosum (Muenster), O. striatum (Sowerby), O. striatulum (Sowerby). See W.L.

Orthoceras vennense *v.* O. cylindraceum.

Orthoceras, sp. (Crick). Found at Polruan. See *Trans. R.G.S.C.*, XII, p. 340, and spec. 940. Compare with O. Vicarii (Whidb.), O. subannulare (Muenst.), and O. barumense (Whidb.).

Orthoceras, sp. Found by Mr. Upfield Green at Fowey. See spec. in Truro Museum.

Orthoceras, sp. (or Actinoceras). Large specimen in slate. Found at Rope Haven by Mr. Thomas Clark and the author, and presented to the Truro Museum.

Orthoceras, sp. Nare Cove. Found by Mr. Upfield Green, and presented to the British Museum.

Phragmoceras (?), sp. Found at Peraver. See *Trans. R.G.S.C.*, XIII, Pl. I, fig. 7. Said to be "silurian, not ordovician." See *Geol. of Mevagissey*, p. 16.

Planulites. See Clymenia.

Poterioceras ellipsoideum (Whidborne). See W.L.

Prolecanites mixolobus *v.* Goniatites mixolobus.

Sphyradoceras Whidbornei *v.* Cyrtoceras nodosum.

Sphyradoceras *v.* Cyrtoceras rusticum.

Tornoceras globosum (Muenster). Trevone. See *Trans. R.G.S.C.*, XI, p. 644.

Tornoceras lineare (Muenster). S. Petherwyn. Spec. in Exeter Museum. See also W.L.

Tornoceras simplex (von Buch). Trevone. See *Trans. R.G.S.C.*, XI, p. 637.

Tornoceras Verneuilli (Muenster). Portquin. See Thomas, *Geol. Mag.*, 1909, p. 97, and Pl. III.

Tornoceras, sp. Found at the Gravel Caverns. See *Trans. R.G.S.C.*, Vol. XIII, p. 53.

5. ECHINODERMS.

Acanthocrinus, sp. Bedruthan. See spec. 1610.

Actinocrinus Simsii. See W.L.

Actinocrinus tenuistriatus (Phillips), A. triacontadactylus (Miller). See W.L.

Adelocrinus hystrix (Phillips). See W.L. and spec. 167.

Ctenocrinus rhenanus, or stellifer. Found at Fowey. See spec. 1520.

Cyathocrinus annulatus (Couch). See W.L. and specs. 138, 139, 140.

Cyathocrinus (?) carinatus. The columnar plates referred here by the author were figured in *Trans. R.G.S.C.*, XII, Pl. D, figs. 6 and 7; see specs. 132, 207.

Cyathocrinus ellipticus (Phillips), C. geometricus (Goldfuss). See W.L.; see also under Sphærocrinus, *infra.*

Cyathocrinus leptos. Found at Crinnis, Polruan, etc. See *Trans. R.G.S.C.*, XII, figs. 9, 11, Pl. D, and specs. 420, 423.

Cyathocrinus megastilus (Phillips). See *Q.J.G.S.*, XXIII, p. 169.

Cyathocrinus macrodactylus. Possibly some of the ill-preserved crinoid fragments from Crinnis and St. Saviour's should be referred here. See specs. 226, 227.

Cyathocrinus nodosus or nodulosus (Phillips). See W.L. and specs. 130, 142, 200, 493; see also *Trans. R.G.S.C.*, XII, Pl. D, figs. 12, 13.

Cyathocrinus pinnatus (Goldfuss). See W.L. and specs. 144, 156–60, 194, 203, 204, 208, etc. Figured *Trans. R.G.S.C.*, XII, Pl. D.

Cyathocrinus planus. See W.L.

Encrinites glomeratus (Couch). See W.L.

Hexacrinus (?). See remarks under Platycrinus, *infra.*

Melocrinus or Rhodocrinus. Found at Bedruthan. See spec. 1625.

Ophiurina (?). See Sympterura.

Periechocrinus (?) moniliformis. See W.L., but probably an error, as this is believed to be strictly a Wenlock limestone form.

Platycrinus. The Cornish crinoid specimens with elliptical stem joints, hitherto referred to this genus as found at East Looe, Pridmouth, and

Crinnis by Peach and others, have not up to the present been critically examined by Wachsmuth and Springer (*Revision*, Part II, p. 66), Phillips's two species of Platycrinus from Devon and Cornwall have been placed with Devonian species from other localities under Hexacrinus. In this latter genus, however, the column joints are cylindrical rather than elliptical, so that Phillips's fig. 39*, Pl. LVIII, can hardly be Hexacrinus.

Rhodocrinus (?). See specs. 155, 1625.

Scaphiocrinus (?). Found at Newtown Bay by Mr. H. Fox. See spec. 1650.

Scyphocrinus, sp. Found at Catasuent Bay, Porthluney. See *Trans. R.G.S.C.*, XIII, p. 193.

Sphærocrinus, sp. Found at Bedruthan Steps. See spec. 1629. This may be the Cyathocrinus geometricus of Goldfuss.

Sphæronites tesselatus (Phillips). See W.L. and specs. 832–5. (This is now recognised to be a sponge.)

Sympterura Minveri (Bather). Found by Mr. H. Fox at Epphaven, and at first referred to Ophiurina (?). See *Trans. R.G.S.C.*, XIII, Pl. II, fig. 6, and p. 752.

6. CRUSTACEANS.

(*a*) Trilobites.

Asaphus Powisii (Murch.). Found at Peraver by Mr. Lake. See *Geol. of Mevagissey*, p. 39.

Calymene Blumenbachii. See W.L., but doubtful.

Calymene Cambrensis (Salter). See W.L. Found

also at Carne, Veryan. See *Trans. R.G.S.C.*, XIII, p. 233, and *Geol. of Mevagissey*, p. 39, and spec. 1903.

Calymene duplicata (Murchison), C. parvifrons (Phillips), C. pulchella (Conrad), C. senaria (Conrad). See W.L.

Calymene Sternbergii (Phill.). See W.L. and spec. 979.

Calymene Tristani (Brong.). See W.L. Also reported from Peraver. See *Geol. of Mevagissey*, p. 39.

Cheirurus Sedgwickii (McCoy). Peraver. See *Geol. of Mevagissey*, p. 39. This species is now put in the sub-genus Eccoptocheile. See *Geol. Mag.*, 1896, p. 120.

Dalmanites (Cryphœus) laciniatus. See Phacops laciniatus.

Homalonotus armatus (Burm.). See *Geol. Mag.*, January, 1903.

Homalonotus (Phacops) Barratti (Woodward). Found at Mother Ivey's Bay. The original specimen is in the British Museum, of which our spec. 1769 is a wax cast. See *Trans. R.G.S.C.*, XII, p. 752, and *Geol. Mag.*, 1903, p. 28.

Homalonotus bisulcatus and H. Vulcani. See W.L.

Phacops (Acaste) apiculatus (Salter). See W.L.

Phacops (Acaste) mimus. See W.L.; also *M.G.S.*, *Geol. of Mevagissey*, p. 39. A spec. in M.P.G. Mr. F. R. C. Reed informs me that the name Acaste is pre-occupied, and that Phacopidella has been applied in place of it and adopted in

America. Probably, however, Phacops apiculatus and Ph. mimus belong to the sub-genus Pterygometopus and not to Phacopidella.

Phacops arachnoides (McCoy). See *Geol. of Plym.*, p. 65.

Phacops batracheus. See W.L. and P. granulatus, spec. 112.

Phacops (Proetus) Dunhevidensis. See Proetus Dunhevidensis.

Phacops ferdinandi (Kayser). Polyne. See Green and Sherborn, *Geol. Mag.*, 1906, and specs. B.M., 17233, 17234.

Phacops granulatus (Muenster). Found on the north shore, east of Cant Cove, by Mr. H. Fox. Named and figured by Mr. H. Woodward. See *Trans. R.G.S.C.*, XIII, Pl. I, figs. 3, 4.

Phacops incertus (Desl.). Peraver. See *M.G.S.*, *Geol. of Mevagissey*, p. 39.

Phacops laciniatus (Salter). See W.L. and spec. 215. This is probably the same as the Dalmanites (Cryphœus) of Hicks. See *Q.J.G.S.*, August, 1897. Mr. Reed regards this as a Dalmanites, and puts this species in the sub-genus Asteropyge. See *Geol. Mag.*, 1905, p. 228.

Phacops latifrons (Bronn.). See W.L. Found also at St. Minver. See *Trans. R.G.S.C.*, XIII, Pl. I, figs. 1a, 1b, 2? See also specs. 115, 1770, 1851–3.

Phacops (Trimerocephalus) anophthalmus (Frech.) Upp. Dev.; Daymer Bay, Cornwall. See Thomas, *Geol. Mag.*, 1909, p. 193, and Pl. VII (spec. 23430, G.S. Coll.).

Phacops (Cryphœus) punctatus (Stein). Found at St. Minver. See *Trans. R.G.S.C.*, XIII, p. 61, and Pl. I, fig. 5, and *Geol. Mag.*, April, 1905. See our spec. 1799 and spec. $\frac{34}{9}$ in M.P.G.

Phacops (Trimerocephalus) lævis (?) (Muenster). Found at Cant Hill and Trevone. See specs. 448, 1800, 1801, 1849.

Phacops (Trimerocephalus) pentops (Thomas). Found by Mrs. Clement Reid in the Upp. Dev. slates near Portquin, with Tornoceras Verneuilli, etc. See Thomas, *Geol. Mag.*, 1909, p. 97, and Pl. III (spec. G.S. Coll., 23068).

Proetus (Phacops) Dunhevidensis (Thomas), Upp. Dev.; Landlake. This is a very perfect specimen about five-eighths of an inch long, which is now in the Southgate Museum at Launceston. See Thomas, *Geol. Mag.*, April, 1909, and Plate VII.

Phacops Sternbergii. See Calymene Sternbergii.

Portlockia. See W.L. and spec. 794 from Giant's Cove. Mr. Reed considers this genus to be inseparable from Phacopidella.

Phillipsia. See W.L.

The following have not yet been found in Cornwall:—

Phacops (Trimerocephalus) tripartitus (Thomas). Upp. Dev.; Whiteway Farm. See Thomas, *ibid.* (specs. 22884 and 23431, G.S. Coll.).

Phacops (Trimerocephalus) aff. cryptophthalmus (Emmer.). Upp. Dev.; Whiteway Farm, near Ideford, in Devon. See Thomas, *ibid.* (spec. 22884, G.S. Coll.).

Phillipsia minor (H. Woodw.), Phillipsia, cf. minor; Phillipsia, sp. These three Phillipsias were all found at Hestow Farm, near Ideford, in Devon. See Thomas, *ibid.* (specs. 23434, 23435, and 23436, G.S. Coll.).

Proetus, α, β, γ. Three specimens found in the Upp. Dev. slates at Whiteway Farm. See Thomas, *ibid.*, specs. 22884, 23432, and 23433, G.S. Coll.

(*b*) ENTOMOSTRACANS.

Barychilina (?) semen (Sandb.). Rooke Hill Quarry. See *Trans. R.G.S.C.*, XIII, p. 153.

Beyrichia. Found in the Lantivet Bay Fish-beds, named by T. Rupert Jones. See spec. 1198.

Cypridina (Entomis) serratostriata (Sandb.). See W.L. Found also at Trevanger Hill Quarry and Rooke Mill Quarry, near Launceston. See *Trans. R.G.S.C.*, XIII, p. 133.

Cypridina (Entomis) gyrata. Found in Rooke Mill Quarry. See *Trans. R.G.S.C.*, XIII, p. 133.

7. FISHES.

The fish-remains hitherto found in the Cornish rocks are very fragmentary, though sufficiently abundant in certain localities, and particularly in Lantivet Bay, near Polperro, and near Portwrinkle, on the south coast, and at Watergate Bay, Bedruthan, and other places along the north coast. They were first discovered and described by Mr. C. W. Peach in 1844, and recognized as such soon after by Hugh

Miller, Sir Philip Egerton, and Sir Roderick Murchison.*

These same remains were afterwards referred to corals (or sponges) under the name of Steganodictyum (S. Cornubicum from Lantivet Bay and Polperro, and S. Carteri from Lantivet Bay and Lower St. Columb Porth) by Prof. McCoy.

Mr. Peach never gave up his belief that they were fish-remains, but the authority of Prof. McCoy prevailed for a time, and his determinations were pretty generally accepted until the year 1865, when Dr. Ray Lankester read a paper to the Geological Society of London in which he maintained that the supposed corals were really fish-remains.

I have not even yet been successful in identifying, or even discovering, all the specimens described and figured so many years ago by Mr. Peach.†

* Sir Philip Egerton had said in a letter to Sir Roderick Murchison that some of the specimens were like Bothriolepis, others like Ctenacanthus, and others again like Onchus tenuiserratus, but "from the general appearance of the collection I should say they differ from any Old Red or Devonian fishes I have ever seen" (see Murchison, *Trans. R.G.S.C.*, VI, p. 320, 1846).

† One of the specimens picked up in 1849, and packed away for nearly twenty years, is described as "a nice but imperfect dorsal plate of Pteraspis. It is 6½ inches in length, beautifully marked with delicate waved lines, and under these in places tubercles, and below all a reticulated network" (PEACH, *Trans. Roy. Geo. Soc. Corn.*, IX, p. 32, 1868). On page 33 he says, "I have enclosed a tracing of my large specimen." This I have not yet found, but the specimen referred to is probably that numbered 1529 in our Collection. Prof. E. Ray Lankester says: "Innumerable remains of the shields of a *Scaphaspis* more than a foot long, fragments of *Cephalaspis*, numerous spines, and other indeterminable fragments, besides the splendid scale and spine assigned by Mr. Pengelly respectively to *Phyllolepis* and *Ctenacanthus*, are the fish-remains of these beds. Mr. Pengelly, Mr. Peach, and the Royal Geological Society of Cornwall have kindly lent me their specimens for further examination" ("Old Red Sandstone Fishes," *Pal. Soc.*, 1870, p. 61).

Fragmentary as they are, they are often very abundant locally and very conspicuous, as Mr. Peach says "most of the fossils [are] of a beautiful shining jet-black, and have that enamelled appearance and granular structure peculiar to the fishes of the Old Red Sandstone."

At Portwrinkle Mr. Pengelly found "a mass of blue slate crowded with ichthyolites, . . . a catacomb of ancient fish," striated and cellular fragments; and, east of this, one specimen 13 inches by 2½ inches, as well as "another rock replete with ichthyolites." Similar masses of almost indeterminable fragments have since been found near Bedruthan by Mr. Howard Fox.

According to Mr. Pengelly, Mr. Hicks (of Looe) had a fine collection (see *Trans. R.G.S.C.*, VII, 1849), but it is not known what became of them. There are many fragments in the British Museum, as also in the Museum of Practical Geology and in the Truro and Penzance Museums, but it must be confessed that so far very little has been discovered which would be recognized as fish by an unscientific observer.

Some of the determinations given below, and particularly as regards the *species*, must be regarded as tentative only for the most part; I, of course, include all the names and synonyms which have been provisionally applied by the various writers to whom reference is made, though it is quite probable that different parts of the same fish have received different names.

AUCHENASPIS EGERTONI. This is a small head-shield from the south coast, exact locality unknown, which was worked out by Mr. Upfield Green.

AUCHENASPIS ORNATUS, see CTENACANTHUS ORNATUS.

ASTEROLEPIS, sp.

Loc. Cross-sand Point, near Looe; Polperro, Lantivet Bay (Peach, 1848; Couch, 1850).

Hugh Miller thought one of the fossils from Lantivet Bay resembled *asterolepis.* "Mr. Pengelly has a fossil resembling an *Asterolepis* shoulder-plate from Cross-sand Point, Looe" (Peach, *Trans. R.G.S.C.*, VII, pp. 123, 313; Pengelly, *ibid.*, p. 213).

Asterolepis (portions of) is figured by Murchison in his *Siluria*, 4th edition, Pl. XXXVII, Figs. 1–3; and the star-like scales from Lantivet Bay, Cornwall, are figured by Mr. Peach (*Trans. R.G.S.C.*, VII, Pl. III, Figs. 1, 2).

BOTHRIOLEPIS. See remarks under HOLOPTYCHIUS NOBILLISSIMUS.

CEPHALASPIS CARTERI (cf. C. Pagei from Forfarshire). A cornu from the Old Mill Quarry near Looe, found by Mr. Upfield Green, has been identified by Mr. A. Smith Woodward. See P.M., spec. 1718 and his note thereon, *Trans. R.G.S.C.*, XII, p. 431.

CEPHALASPIS LYELLII. Polperro (Peach, 1844; Couch, 1850). Mr. Peach found many fragments which he thought to belong to this species at Polperro in 1843, including "part of a lateral horn" and certain "scales," "rhomboidal and lozenge-shaped as in Miller, Pl. VI, VII, VIII." Also "long specimens, each end divided into a pyramidal form locking alternately into the adjoining scales."

CEPHALASPIS ORNATUS, see CTENACANTHUS ORNATUS.

CHEIRACANTHUS (?), sp. Polperro (Peach, 1844).

A group of scales, which Mr. Peach refers to this species, is beautifully figured by him in *Trans. R.G.S.C.*, VII, i, Figs. 5, 6.

CLIMATIUS. A fragment which Mr. A. Smith-Woodward has referred to this genus, was found at Watergate Bay by Mr. Howard Fox. See P.M. 1675. Later, Mr. Fox found other fragments at Bedruthan. P.M. 1630, 1635, 1727. See *Trans. R.G.S.C.*, XII, Pl. XVI, Figs. 9, 10.

COCCOSTEUS. A specimen from North Cornwall referable to this genus was found by Mr. A. Smith-Woodward in Mr. Winwoode Reade's collection "An Upper Devonian form." The specimen P.M. 691 from Trevone, found and presented by Mr. Howard Fox, is "Coccostean, not Coccosteus, perhaps Heterosteus or Homosteus." It is a thick tuberculated and granulated fragment, not striated.

CTENACANTHUS ORNATUS. Polperro (Peach, 1844).

Murchison figures a portion of the spine of this fish in *Siluria*, Pl. XXXVII, Fig. 6.

The Cornish specimens variously referred to *Cephalaspis ornatus* and *Auchenaspis ornatus* are perhaps to be referred here. Probably the same as Ray Lankester's *Hemicyclaspis Murchisonii*. A coarsely striated spine from Watergate Bay has been referred provisionally to this genus by Dr. Traquair. See *Geol. of Newquay*, 1906, pp. 8, 11.

DIPTERUS. A fragment from North Cornwall found among Mr. Winwoode Reade's specimens by Mr. A. Smith-Woodward has been referred to this genus.

EUKERASPIS PUSTULIFERUS. See W.L. Was reported from Polruan by Couch in 1850, but this was probably a mistake.

HETEROSTEUS. See under Coccosteus, *supra*.

HOLOPTYCHIUS NOBILLISSIMUS (?). Polperro (Peach, 1844). According to Murchison, Peach's specimen was *not H. nobilissimus.* Prof. Ray Lankester mentions, in a private note with which he favoured me in 1881, "a scale like *Holoptychius.*" "The so-called scales of Holoptychius from Devonshire described by J. Phillips (*Pal. Foss.*) do not pertain to this genus" (Woodward, *B. M. Cat.*, p. 330, note).

HOMOSTEUS. See under Coccosteus, *supra.*

ICHTHYODORULITES, or *Fish-defences*, are found in considerable abundance, and have been provisionally referred to *Onchus* and *Ctenacanthus.*

ONCHUS. Polperro and Lantivet Bay (Peach, 1844, 1847). The beautiful spines from the above localities, figured by Peach, *Trans. Roy. Geo. Soc. Corn.*, Pl. I, Figs. 1–4, were not unlike *O. tenuirostris* or *O. tenuiserratus* of Egerton and Agassiz. Murchison says, "may perhaps be a *Ctenacanthus*" (see *Trans. Roy. Geo. Soc. Corn.*, VI, p. 320). A spine "from the north coast," according to Peach (*Trans. Roy. Geo. Soc. Corn.*, VII, pp. 100–105).

PAREXUS. A slender spine found at Watergate Bay has been referred to this genus by Dr. R. H. Traquair. See *Geol. of Newquay*, 1906, p. 11.

PHLYCTÆNASPIS (cf. Ph. acadica). A fragment in soft grey shale from Watergate Bay found by Mr. H. Fox, P.M. 1676, has been referred to this genus by Mr. A. Smith-Woodward. See *Trans. R.G.S.C.*, XII, p. 361, and Pl. XVI, Figs. 5, 6.

PHYLLOLEPIS CONCENTRICUS.

A scale from "near Looe" from the collection of Mr. Pengelly is now in B.M. It looks like a fragment of Pteraspis Cornubica of rather coarse striation.

PTERASPIS CARTERI. See Cephalaspis Carteri.

PTERASPIS CORNUBICA. The fine specimen P.M. 1529 is "the hinder portion of the median disc of the dorsal armour, with the base of the median spine rising as usual from a short longitudinal fissure in the posterior margin of this plate . . . the shield probably measured 0·25 m. in length." A specimen in the British Museum (P. 7156) is "a smaller fragment of the median disc with the base of the posterior spine." Another specimen (P. 7155) "is a detached left orbital plate shaped precisely as in the typical P. rostrata." All the above-mentioned specimens have been identified by Mr. A. Smith-Woodward. See *Trans. R.G.S.C.*, XII, p. 229.

PTERASPIS CROUCHII. A fragment of a rostrum from Lantivet Bay. P.M. 1886 is perhaps referable to this species.

SPHAGODUS PRISTODONTUS.

Polperro and Lantivet Bay (Peach, 1844, 1847, etc). This tenative determination has not been confirmed.

NOTE.—Many dark coprolitic bodies are found in the slates and shales of Polperro and Fowey. These contain both lime and phosphoric acid, but the few which have been examined in thin sections under the microscope do not exhibit any marked evidence of organic structure.

8. PLANTS.

Remains of plants are extremely rare, except in the dark carbonaceous shales of the Bude region, and being usually pyritous, they are often ill-preserved while *in situ*, and readily destructible when

placed in museums. The following are all which have been provisionally determined so far as I am aware.

Alethopteris lonchitica (Schloth.), found at Welcombe Mouth, in Devon, one mile north of the Cornish boundary; not yet found in Cornwall. See E. A. Newell Arber, *Q.J.G.S.*, 1907, p. 249.

Asterophyllites. Plants referred to this genus, but of undetermined species, occur at Bude according to Morris, as in the corresponding beds in N. Devon.

Calamites. Fragments, with other reed-like stems, are found in the road cutting between Callington and Launceston, "about four miles from Callington," according to Pattison.

Calamites nodosus. Probably occurs in the neighbourhood of Bude and Truscott, as in the corresponding beds in N. Devon.

Calamites ramosus (Artis), near Bude. Reported by E. A. Newell Arber. *Q.J.G.S.*, 249, Feb., 1907.

Calamites Steinhaueri. Probably occurs in the neighbourhood of Bude and Truscott, as in the corresponding beds in N. Devon.

Calamites Succowi (Brongn.). Somewhat doubtfully determined in specimens from Bude by Mr. John Morris in MS. notes given to Mr. Pattison. Reported from near Bude by Mr. E. A. Newell Arber, *Q.J.G.S.*, 249, Feb., 1907.

Calamocladus. cf. Equisetiformis found at Speke's Hill Mouth, in Devon, but near the Cornish boundary. See E. A. Newell Arber, *Q.J.G.S.*, 1907, p. 249.

Cyperites. Somewhat doubtfully determined in specimens from Bude according to Mr. John Morris. cf. Dactylothera plumosa (Artis). Higher Sharpnose Point. Newell Arber, *ibid.*

Eophyton. Reported somewhat doubtfully by Mr. Peach from the quarry opposite the mineral floors at Hayle. "Calamite-looking impressions." See *Trans. R.G.S.C.*, IX, p. 57.

Fruits (undetermined). Reported from Bude by Pattison and others.

Fucoids. S. Petherwyn, Port Wrinkle (1 mile east of), Lantivet Bay, etc. See also vegetable impressions, *infra.*

Lepidodendron. Bude (?).

Mariopteris muricata (Schl.). Found at Speke's Hill Mouth, near Highland Quay, in Devon, but near the Cornish boundary. See E. A. Newell Arber, *Q.J.G.S.*, 1907, p. 249.

Neuropteris giganteus. Doubtfully reported from Bude specimens by Mr. John Morris.

Nematophycus(?) Hicksii. Gunwallo. Spec. 1600, 1716, etc. See *Trans. R.G.S.C.*, XII, p. 437 and Pl. 17.

Poacites. Various undetermined species occur at Bude and Truscott according to Mr. John Morris.

Stigmaria ficoides (Sternb.). Newell Arber, *ibid.*

Sigillaria incervularia. Doubtfully determined from Bude specimens by Mr. John Morris.

Sphenopteris obtusiloba (Brongn.). Newell Arber, *ibid.*

Sternbergia. Doubtfully determined from Bude specimens by Mr. John Morris.

Vegetable impressions. Roseland (Giles, *Trans. R.G.S.C.*, VII, 93), Newquay (Pattison), and Polruan.

Royal Geological Society of Cornwall.

THE NINETY-SEVENTH

ANNUAL REPORT

ETC.

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F. G. Brook Fox, F.G.S., Porth Navas, Penryn.
T. W. F. Hall, School of Mines, Camborne.
F. Harvey, Glanmôr, Hayle.
Rev. Prebendary Hedgeland, Penzance.
F. Holman, Penzance.
Mrs. Husband, Trefusis, Westbourne Park Road, Bournemouth.
J. B. Jennings, Johannesburg, South Africa.
Sir E. Durning Lawrence, Ascot, Berkshire.
F. Latham, Penzance.
C. D. N. Le Grice, Trereife, Penzance.
F. W. Millett, Eniscoe, Brixham, Devon.
E. V. Newton, Camborne.
The Earl of Mount Edgcumbe, Mount Edgcumbe, Devonport.
H. Palmer, East Howle Colliery, Ferryhill.
M. Paroksamy, Hyderabad, India.
R. Pearce, 43 St. George's Court, Gloster Road, S.W.
G. Pearce, Hayle.

W. C. Pendarves, Pendarves, Camborne.
R. H. P. Preston, Penzance.
W. Rogers, Lamorva, Falmouth.
Rev. St. A. Molesworth St. Aubyn, Clowance, Camborne.
Sir George Smith, Treliske, Truro.
F. J. Stephens, F.G.S., Ashfield, Falmouth.
John Symons, Penzance.
R. A. Thomas, Dolcoath, Camborne.
Sir W. Trevelyan, Nettlecombe Court, Taunton.
Sir A. P. Vivian, F.G.S., James Street, Buckingham Gate, W.
J. Westlake, K.C., 3 Chelsea Embankment, S.W.
J. C. Williams, Caerhayes Castle, St. Austell.

ASSOCIATES.

J. T. Blight, F.S.A., Penzance.
W. Gregor, Swansea.
R. T. Hall, Cape Copper Mines, South Africa.
W. Hollow, Leyton, Essex.
B. Kitto, F.G.S., 26 Lancaster Road, Finsbury Park, N.
S. Mitchell, Swansea.
F. Oats, F.G.S., St. Just.
J. Phillips, Australia.
T. B. Provis, A.I.C.E., Finsbury Chambers, E.C.
John Rowe, St. Just.
Rev. D. G. Whitley, Baldhu, Scorrier.

The Secretary requests the favour of his being informed of any inaccuracies in the foregoing lists.

PRESIDENTS

Since the Foundation in 1814.

1814–1839. Davies Gilbert, Esq., M.P., F.R.S., etc.
1840–1856. Sir Charles Lemon, F.R.S., etc.
1857–1862. Augustus Smith, Esq.
1863–1867. Charles Fox, Esq., F.G.S.
1868–1870. H. Seymour Tremenheere, Esq., F.G.S.
1871–1879. Sir Warington Smyth, F.R.S., etc.
1880–1881. Sir A. P. Vivian.
1881–1882. Lord Courtney of Penwith.
1883–1890. Sir Warington Smyth, F.R.S., etc.
1891–1892. Lord St. Levan.
1893–1894. Howard Fox, Esq., F.G.S.
1895–1896. T. R. Polwhele, Esq., F.G.S.
1897–1900. J. D. Enys, Esq., F.G.S.
1901–1902. Sir C. Le Neve Foster, F.R.S., etc.
1903–1904. J. H. Collins, Esq., F.G.S.
1905–1906. Dr. R. Pearce, F.G.S.
1907–1908. A. K. Barnett, F.G.S.
1909–1910. W. Colenso, Esq.
1911–1912. J. H. Collins, F.G.S.

THE

ANNIVERSARY ADDRESS OF THE PRESIDENT,

WILLIAM COLENSO, Esq.,

To the General Meeting, November 8th, 1910.

THE HYDRO-GEOLOGY OF CORNWALL.

Ladies and Gentlemen,—It seemed to me that an appropriate subject for a paper to be read before the Royal Geological Society of Cornwall should be that upon which it is my endeavour to present before leaving the chair, which I have had the honour of occupying for the second year.

From my association with the work of the Waterworks of Penzance, of which committee I have been a member for the past twelve years, and of which I have occupied the chair during the past two years, I have had opportunities of coming into contact with many difficulties and conditions in the Hydro-geology of the formations of this county. Although I do not pretend to cover anything but the fringe of this wide subject, I feel that my observations will form a nucleus of what may be hoped to follow by other authors.

The question of Hydro-geology is of growing importance to Cornwall. As the towns and villages grow in public favour, so they must provide increased and pure supplies of water. Water is required in more abundance in districts where developments are made in sanitation—where sewers need flushing and cleanliness is regarded as indispensable. But the geology of the formation of the earth's crust is the all-important factor to be looked to in many instances for the supply of this need in a pure and plentiful quality and quantity.

Water for all uses can have but one first source, viz. the rain and moisture in the atmosphere. Water falling on the earth's surface may be caught and stored in reservoirs or taken from rivers or streams and artificially stored for use. On the other hand, that which soaks away into the ground may be obtained by wells or, as is sometimes the case, at its emergence in the form of springs.

It has been laid down as an axiom that pure air, pure water, and nutritious food are the three great agents for promoting life and health. The word "pure" as used signifies as free as possible from deleterious matter. Napoleon once said to Antonomarchi at St. Helena: "Life is a fortress which neither you nor I know anything about. Why throw obstacles in the way of its defence? Water, air, and cleanliness are the chief articles in my pharmacopœia."

On the best authority I can state that the legitimate use of water is steadily being popularized, calling for an increased average quantity for domestic use; and this is especially the case in Cornwall, where even the remotest villages are rapidly gaining favour as holiday resorts.

As a test to ascertain the quality of water, I would quote Heisch's simple method as contained in the *Pharmaceutical Journal*:—

"Good water should be free from colour, unpleasant odour and taste, and should quickly afford a good lather with a small proportion of soap.

"If half a pint of water be placed in a clean, colourless, glass-stoppered bottle, a few grains of the best white lump sugar added, and the bottle fully exposed to the daylight in the window of a warm room, the liquid should not become turbid, even after exposure for a week or ten days. If the water becomes turbid, it is open to grave suspicion of sewage contamination, but if it remains clear, it is almost certainly safe."

In Cornwall, besides the question of production, that of purity is of great importance as a matter for consideration, as owing to the quantity of minerals in existence in some water, they may

render the supply totally unfit for consumption. The effect of bad water may not be immediately noticeable, but sooner or later very injurious effects may result therefrom.

I cannot do better than to quote a scientific definition of polluted water laid down by Professor Frankland, in which he clearly defines a minimum limit, when, in his opinion, water contains sufficient mechanical or chemical impurities in suspension or solution to entitle it to be considered bad or a polluted liquid :—

"Every liquid which has not been submitted to precipitation produced by a perfect repose in reservoirs of sufficient dimensions during a period of at least six hours, or which, having been submitted to precipitation, contains in suspension more than one part by weight of dry organic matter in 100,000 parts of liquid, or which, not having been submitted to precipitation, contains in suspension more than three parts by weight of dry mineral matter or one part by weight of dry organic matter in 100,000 parts of liquid.

"Every liquid containing in solution more than two parts of weight of organic carbon or three parts of organic nitrogen in 100,000 parts of liquid.

"Every liquid which, when placed in a white porcelain vessel to the depth of one inch, exhibits under daylight a distinct colour.

"Every liquid which contains a solution, in every 100,000 parts by weight, more than two parts of any metal, except calcium, magnesium, potassium, and sodium.

"Every liquid which in every 100,000 parts by weight contains in solution, suspension, chemical combination, or otherwise, more than 0·5 part of metallic arsenic. (This is higher than the percentage usually allowed at the present time.)

"Every liquid which, after the addition of sulphuric acid, contains in every 100,000 parts by weight more than one part of free chlorine.

"Every liquid which in every 100,000 parts by weight contains more than one part of sulphur in the state of sulphuretted hydrogen or of a soluble sulphuret.

"Every liquid having an acidity superior to that produced by adding two parts by weight of hydrochloric acid to 1000 parts of distilled water.

"Every liquid having an alkalinity greater than that produced by adding one part by weight of caustic soda to 1000 parts of distilled water.

"Every liquid exhibiting on its surface a film of petroleum or hydrocarbon, or containing in suspension in 100,000 parts, more than 0·5 of such oils."

In spring water there are certain harmless impurities which are sometimes considered beneficial in drinking water when present in quantities not exceeding ten grains to the gallon.

The medical properties of carbonate of magnesia, a mild cathartic, and of its sulphate (Epsom salts), a mild purgative, and of carbonate and nitrate of potassa (pearlash and saltpetre), and of bromide of potassium, a mild diuretic, are well known, and have their uses in water, whilst calcium as common lime, and sodium, common sea-salt, and silica as the property of common sand, are among the harmless when in small quantities, and are present in most waters. They are usually accompanied by an oxide of iron. Of course the quantity of silica in water is minute.

Spring waters, in passing through the earth, are thoroughly filtered and freed from all suspended matters of impurity, and therefore they are always the most clear and sparkling of all natural waters.

It might be noted that the quantity of chlorine found in water in Cornwall ranges from three to five grains per gallon. I have it on the best authority that the chlorine is generally high in all Cornish water, and that even five grains does not as a rule indicate pollution from a dangerous source. This is an important fact which must be of interest from a geological point of view.

The impurities which are present in the streams should be seldom other than dissolved vegetable matter, and the natural mineral impurities already named, together with sand and clay,

in suspension. It is the artificial impurities that cause the danger of pollution in our streams: they are open to become fouled in their flow, and are therefore less sought after for drinking purposes.

In order, then, to obtain the spring water where there are no streams, or where a more wholesome supply of water is desired, a study of geology other than from a purity point of view is essential. I shall therefore proceed to illustrate some experiences with which I have come into contact.

It has been stated that Arago's prediction of a store of potable water in the deep dipping greensand stratum beneath the city of Paris was "one of the most brilliant applications of geological science to useful purposes." A multitude of his fellow citizens were suffering a general physical deterioration for want of wholesome water, when he, possessing a genius such as Cicero believed to be "in some degrees inspired," made an exploration of the subterranean depths in 1833, and at a depth of 1806 feet 9 inches he tapped that well-known spring at Grenelle, which rose from its depths to overflowing.

Those wonderful prolific greensand strata do not, however, exist in Cornwall, but we have many formations sufficiently productive of water to satisfy the requirements of those in our midst.

We have subterranean basins, which store up the rain percolations and deliver them to the springs or wells in constant flow, in like manner that surface lakes gather the floods and feed the streams with continuous delivery.

These basins are frequently the dip of a porous stratum lying between two or more impervious strata. Frequently we may conceive that these impervious basins, filled with alluvial deposit, may have at one time been the sites of deep lakes which have gradually silted up and become land.

These natural reservoirs contain water free from all suspended matter, and are usually to be found on the hill-side or in some valley where the tendencies have been favourable to the deposit of drift

On examining the crust of the earth it will be found that the

deposited material will thin out at distances from the greater deposit, and under this will be found a vein of decomposed granite gravel overlying the impervious granite. In this case it is only necessary to bore down through the alluvial deposit until the decomposed granite is reached, and the result must be similar to that achieved by Arago in the case of greensand. The close clay usually found on the surface of these filled-up creeks changes into clay-slate at no great depth, and is capable of containing a large percentage of stored water, such as was the case at the Polteggan Well, which supplies Penzance with water. The conditions which existed there have been closely observed by me, and can be testified to by others familiar with the work, especially Mr. Alderman Carne. Mr. Frank Latham stated before the British Association of Water Engineers "that the overlying stratum of dense clay was a favourable feature of the formation in question, as surface pollution of the water in the killas is absolutely prevented thereby." Mr. Latham informs me that abundant supplies are drawn from the alluvial formations in America, as at Brooklyn, where extensive deposits are found, a supply of twenty-five million gallons per day is thus obtained.

The deposits to be found in Cornwall are not very extensive, yet they must be looked upon as prolific and sufficient for most purposes in this district.

In some districts where there is an absence of the particular deposit in question another formation sometimes presents itself resembling clay, viz. china-clay formations. China-clay formations are also prolific water-bearing strata. By testing the weight of china-clay, when wet and again when dry, it will be found that it contains at least a quarter of its weight in water—so that boring through this clay the water is let down in abundant quantities to be replenished according to the natural rules of nature by atmospheric influences. There is likewise an underflow in many china-clay districts, where the supporting formation is impervious. This is especially the case where there is a seam or stratum of loose granite-gravel underlying the china-clay formations such as exists at some of the water-supply works in Cornwall.

In the district of Ding Dong there is much china-clay, and I have seen springs issuing therefrom in the district of Bosiliack at the driest periods of the summer season. In fact, at the latter end of the dry season of last year an attempt was made to sink a well near this spot, and the utmost difficulty was experienced owing to the wet nature of the formation.

In the districts around London it is usual for an underground water survey to be made before attempting to lay down a water-supply undertaking. This is done by periodically measuring the depth of the water in the wells in the district and thereby ascertaining the fluctuation of the subsoil water. In Cornwall the conditions are quite different, as the flow of underground water is governed entirely by geological formations varying in an irregular manner. Mr. Latham says on this point: "Should it be found that a flow of underground water takes place over the impervious granite, as is frequently the case where there is a stratum of decomposed granite of varying depth overlying the granite, particularly on an inclined plane, the flow will be almost entirely intercepted by the presence of an Elvan Dyke or course, which, owing to its open construction, forms a channel to divert and direct flow. The water thus intercepted will sometimes find a ready outlet at the nearest cross-course, because these cross-courses are composed of loose material filling up fissures which are probably faults or gaps of unknown depth.

"The elvans, which are composed of igneous rock, and are of earlier origin than the cross-courses, assume a direction from east to west, whilst the cross-courses run from north to south or thereabouts, intersecting the elvans almost at right angles."

I have made several visits in the direction of the elvan dykes referred to, and the outcrop of water in the form of springs is visible in many places, there being one at the foot of the hill at Little Sellan, and several were found to overflow from under the clay below the fields in the neighbourhood of Trengwainton.

My successor in this chair is now passing through the press his forty years' *Observations on the West of England Mining Region.* He is issuing this important work at his own cost and risk, and will be glad to receive the names of subscribers thereto. Follow-

ing the Henwood precedents in regard to Vols. V and VIII, the Council has arranged with Mr. Collins that his work shall form the fourteenth volume of our *Transactions*. As the issue of the thirteenth volume will be in no way impeded or delayed, it was felt that the Society would not be in a position to pay for copies for free issue to its members, as was done in the cases already mentioned.

The Council has however shown its good will by subscribing for a few copies, and has provided for a further subscription on favourable terms, so that it may be in a position to deal with the more important of the Societies with which it exchanges publications.

LADIES AND GENTLEMEN,—On behalf of this Society I present the "William Bolitho" Gold Medal to Dr. G. J. Hinde, who has done very valuable work in Cornish geology.

It gives me much pleasure in presenting this medal to him; it marks the very high esteem and appreciation in which the Council regard his researches, and with them I hope he will continue his geological studies of our county, and by so doing increase the knowledge of our Society.

PENZANCE, *November*, 1910.

In accepting the medal on behalf of Dr. Hinde, Mr. Howard Fox, in reply, read a letter from Dr. Hinde, in which he expressed his regret at not being able to receive the medal in person, and continued as follows:—"I shall be glad if you will let the Council and the Society know that I am proud of the honour which they have done me in awarding me their medal, and greatly value their recognition of my geological work."

Mr. Fox said that Dr. Hinde was the leading authority on many of the less highly developed forms of animal life, especially of those which could only be studied by the use of the microscope. His papers described and his sketches illustrated specimens of corals, sponges, radiolaria, and other minute organisms from all parts of the world.

Mr. Fox added that he was personally indebted to Dr. Hinde for invaluable assistance in correctly naming the fossils from the north coast of Cornwall, described in the *Transactions* of their Society. If the specimens were outside Dr. Hinde's special departments, he would consult the leading authorities on the other divisions of the animal kingdom, sparing neither time, trouble, nor expense in order to make the papers as complete as possible.

LIST OF PAPERS BY DR. GEORGE J. HINDE, F.R.S., CONNECTED WITH CORNISH GEOLOGY.

1893. Note on the Radiolaria in the Mullion Island Chert.—*Quart. Journ. Geol. Soc.*, Vol. XLIX, May, pp. 215–18, Pl. IV.

1895. Joint paper: Hinde, G. J., and Fox, Howard.

On a well-marked horizon of Radiolarian Rocks in the Lower Culm measures of Devon, Cornwall, and West Somerset.—*Quart. Journ. Geol. Soc.*, Vol. LI, pp. 609–68, Pls. XXIII.–XXVIII.

1896. Joint paper: Hinde, G. J., and Fox, Howard.

Supplementary Notes on the Radiolarian Rocks in the Lower Culm measures to the West of Dartmoor.—*Trans. Devon Assoc.*, Vol. XXVIII, pp. 774–89. Sketch Map.

1898. Joint paper. Notes on Veryan and other Limestones associated with Radiolarian Cherts in South Cornwall. Howard Fox. With Notes and Sketches by G. J. Hinde. *Trans. Roy. Geol. Soc., Cornwall*, Vol. XII, pp. 179–84, 1 pl.

1899. On Radiolaria in Chert from Chypons Farm, Mullion parish, Cornwall.—*Quart. Journ. Geol. Soc.*, Vol. LV, pp. 214–19, Pl. XVI.

REPORT OF THE COUNCIL

To the Annual General Meeting, November 8th, 1910.

THE Council are confident that in submitting to H.M. King George V the expression of the sincere regret with which the Society received the news of the great loss sustained, not merely by the Empire, but by the whole world, by the death of H.M. King Edward VII, and of their loyalty to his successor, they were acting thoroughly in accordance with the feelings of the members.

The Council are glad to be able to announce that H.M. King George V has been graciously pleased to continue to afford the Society the royal patronage which has been enjoyed now for nearly one hundred years, and at the same time to approve that H.R.H. the Prince of Wales should be the Vice-Patron.

The Council have arranged with Mr. J. H. Collins that his forthcoming work, *Observations on the West of England Mining Region*, shall be issued as Vol. XIV of our *Transactions*.

There can be no doubt that a book by such an authority on a subject with which he is so well acquainted must rank as a standard work and form a fitting sequel to Vols. V and VIII, which contained Mr. W. J. Henwood's "Metalliferous Deposits of Cornwall and Devon."

The Council have during the year been carefully considering the necessity of providing the additional floor and wall space which has become necessary to accommodate the steadily increasing collections, both of specimens and books. They finally decided to make use of the vacant space at the top of the stairs by making a landing across. The work has been most efficiently

carried out by Mr. H. Carne, and they hope that the members will be pleased both by the adaptation of a waste space for useful accommodation and by the way in which it has been done at a comparatively small cost.

The Council have also granted to the Public Buildings Company, Ltd., permission to make an emergency exit from the gallery of St. John's Hall through the western wall and across the back-yard of the Society's premises.

With sincere regret the Council record the death during the past year of Mr. T. W. Field, of Marazion.

Mr. Field had been a member since 1875, and filled a seat on the Council since 1885. His connection with the Chyandour Smelting Works had made him one of the most prominent figures in the Cornish mining world, and his genial disposition and upright character commanded the affection and respect of all who knew him.

The Council have decided to award the "William Bolitho" medal for the year to Dr. G. J. Hinde, F.R.S.

The Society recognized Dr. Hinde's eminent position as a geologist and his services to the work of this Society as long ago as 1898 by electing him an honorary member, and the Council feel sure that they will appreciate the appropriateness of the award now.

LIBRARIAN'S REPORT.

1910.

THE Librarian acknowledges, with thanks, the receipt of publications from the following:—

American Philosophical Society.
—— Academy of Arts and Sciences.
—— Geographical Society.
—— Institute of Mining Engineers.
Batavia. Jaarbock.
Belgium. Soc. Roy. Zoologique.
——. Soc. Géologique.
Bristol Naturalist's Society.
British Association.
Canada. Geological Survey.
——. Department of Mines.
——. Royal Society.
Canadian Institute.
Cape of Good Hope. Geological Survey.
Cincinnati. Society of Natural History.
Colorado Scientific Society.
Cornwall Royal Polytechnic Society.
——. Royal Institution.
Denmark. Dansk Geologisk Forening.
Dorpat. Naturforscher Gesellschaft bei der Universitat Jurjew.
Dublin Royal Society.
Edinburgh Royal Society.
—— Geological Society.
Elisha Mitchell Scientific Society.

Geological Society.
Geologists' Association.
India. Geological Survey.
Indiana. Academy of Science.
Iowa. Geological Survey.
Leicester Literary and Philosophical Society.
Liverpool Geological Society.
—— —— Association.
London and West Country Chamber of Mines.
Manchester Geographical Society.
Maryland Geological Survey.
Mexico. Instituto Geológico.
——. Sociedad Geologica.
Michigan. Academy of Sciences.
Milwaukee Public Museum.
Missouri. Bureau of Geology.
Monte Video. Museo Nacional.
New York Academy of Sciences.
New South Wales. Geological Survey.
——. Royal Society.
New Zealand. Department of Mines.
Normandy. Société Géologique.
North of England Institute of Mechanical and Mining Engineers.
Nova Scotia. Institute of Science.
Oklahoma University.
Peru. Cuerpo des Ingeniores de Minas.
Philadelphia. Academy of Natural Sciences.
Plymouth Institution.
Queensland Government.
Royal Society of Arts.
Royal Society.
Romaniei Institutului Geologic.
Saxony. Berg und Huttenwesen.
Smithsonian Institution.
Tuscany. Societa di Scienzi Naturali.
United States. Geological Survey.
Upsala. Geological Institute.

Uralian Society of Natural Sciences.
Vienna. K. K. Geologischen Reichsanstalt.
——. K. K. Naturhistorichsen Hofmuseums.
Victoria. Geological Survey.
Western Australia. Geological Survey.
——. Department of Mines.
Wisconsin Academy.
Yorkshire Geological Society.

[*From the Authors.*]

The Lignite of Bovey Tracey. C. Reid and E. M. Reid.
Scandium. Prof. Eberhard.

[*Purchased.*]

Palæontographical Society. Vol. LVIII.
London, Edinburgh, and Dublin Philosophical Magazine.

CURATOR'S REPORT.

ADDITIONS TO MUSEUM.

1910.

	Presented by
Graphite in Elvan. From Polmennor Quarry.	W. Colenso.
Chalcedony in Elvan. Polmennor.	W. Colenso.
Flint with Depressions. Mousehole.	J. Symons.
Iron Concretions. North Devon.	"
Crystals of Andalusite. Wheal Coates.	
Pinite. Tregarthen Zennor.	
Dichroite. Germoe.	

THE WILLIAM BOLITHO MEDAL,

which is provided for by a fund bequeathed to the Society for the purpose by William Bolitho, of Ponsandane, in 1895, has been awarded to the following members :—

1896. R. Etheridge, F.R.S.
1897. Howard Fox, F.G.S.
1898. J. H. Collins, F.G.S.
1899. F. W. Millett, F.R.M.S.
1900. Sir C. Le Neve Foster, F.R.S., etc.
1901. Thomas Clark.
1902. Dr. Richard Pearce, F.G.S.
1903. W. A. E. Ussher, F.G.S.
1904. J. D. Enys, F.G.S.
1905. Lady Warington Smyth.
1906. A. K. Barnett, F.G.S.
1907. U. Green, F.G.S.
1908. T. R. Polwhele, F.G.S.
1909. Rev. D. G. Whitley.
1910. Dr. G. J. Hinde, F.R.S., etc.

W. BOLITHO MEDAL ACCOUNT.

Dr.	£	s.	d.	Cr.	£	s.	d.
November 10th, 1910—				November 10th, 1909—			
To Gerrard and Co. for Gold Medal	12	10	0	By Balance	7	1	5
,, Balance	12	7	4	February 15th, 1910—			
				,, Dividend on £540 Great Western and Great Central 3½% Stock	8	17	11
				August 15th, 1910—			
				,, Ditto, ditto	8	18	0
	£24	17	4		£24	17	4
				November 10th, 1910—			
				By Balance	12	7	4

STATEMENT OF RECEIPTS AND EXPENDITURE FOR THE YEAR 1909–10.

Dr. *The Treasurer in Account with the Royal Geological Society of Cornwall.* **Cr.**

Receipts.

November 8th, 1910—	£	s.	d.	£	s.	d.
To Balance from 1909				54	17	8
,, Ordinary Subscriptions and Arrears	31	10	0			
,, Subscription per His Royal Highness the Prince of Wales . . .	20	0	0			
,, One Year's Dividend on £1800 Midland Railway 2½ % Debenture Stock, £45, less tax £2 12*s.* 6*d.* .	42	7	6			
				93	17	6
,, Sale of transactions . . .					2	6
				£148	16	8
November 8th, 1910—						
To Balance in Treasurer's hands				£13	7	5

Expenditure.

November 8th, 1910—	£	s.	d.	£	s	d.
By Rates and Taxes	0	8	0			
,, Curator's Salary	42	7	6			
,, *Transactions*, Periodicals, Printing, and Stationery	44	8	0			
,, Fire Insurance Premium . .	2	12	9			
,, Extra Fire Insurance Premium .	1	18	0			
,, Coals and Gas	15	13	11			
,, Repairs to Buildings, etc. . .	3	13	4			
,, Palæontographical Society 1909-10	2	2	0			
,, New Book Case for Library . .	9	10	0			
,, Painting exterior of Premises .	9	12	6			
,, Postages, Carriage of Specimens and Petty Disbursements . .	1	16	9			
,, Cost of transferring Stock in new Trustees' names	1	7	6			
				135	10	3
,, Balance				13	7	5
				£148	17	8

T. R. BOLITHO, *per pro*, *Treasurer.*

LIST OF PAPERS

READ TO AND PUBLISHED BY THE SOCIETY.

1910.

President's Address. W. Colenso.

The Flint Implements of North Cornwall and their Relationship to Local Earthworks. Henry Dewey, F.G.S., of H.M. Geological Survey.

The Application of so-called "Rare" Metals to Modern Commercial Use. F. J. Stephens, F.G.S., M.I.M.M., M.I.M.E.

THE FLINT IMPLEMENTS OF NORTH CORNWALL AND THEIR RELATIONSHIP TO LOCAL EARTHWORKS.

By Henry Dewey, F.G.S., of H.M. Geological Survey.

Whilst engaged in the geological survey of North Cornwall during the past four years I carefully noted the occurrence and distribution of worked flints and other objects of archæological interest. Most of the earthworks, barrows, and the like have been described, but there are many districts from which discoveries of worked flints have not apparently been fully reported.* Nor has the relationship between the flints and earthworks been specially considered, and for this reason it seems desirable to place on record such an account as is possible to give from imperfect evidence.

I was unable to find a large number of well-formed flints, but flakes were common at special localities and absent from comparatively wide intervening areas. These productive localities in practically every instance are situated upon high land and often near encampments; but before describ-

* See, however, Rev. D. G. Whitley, *Journ. Roy. Inst. Cornwall*, Vol. XV, p. 267, and F. Brent, *op. cit.*, Vol. XIV, p. 417, and Vol. IX, 1886.

ing the finds, a brief account of the confines and physical features of the area surveyed will be given.

CONFINES AND PHYSICAL FEATURES OF THE AREA.

The area is bounded by the coast between Stepper Point (Padstow) and Crackington Haven (St. Gennys) on the west, the low hills south of Launceston on the east, while southward the River Camel practically constitutes a boundary line, and the high moors between Beeny Cliff and Launceston form the northern limit. The area contained by these boundaries consists centrally of an elevated tract of moorland (Bodmin Moor) mostly over 1000 feet above sea-level, which rapidly slopes down on three sides to rolling hills some 300 to 400 feet high. On the north of Bodmin Moor a large spur of high ground stretches from the moor to the coast near Boscastle, sending side spurs southward past Camelford and Delabole. These lower hills are part of an old plateau which has been dissected into ridges and deep valleys by the rivers Camel, Alan, and Vallency.

When viewing the present highly cultivated state of North Cornwall in the area west of the moors it is difficult to picture its original wildness. The dreary upland bogs and wide stretches of rocky heathland of the moors are probably very little changed from their earlier condition, but the cultivated fields have replaced dense thickets of oak and brier. Marshes and thick jungles of sodden

and matted vegetation, impenetrable except to wild beasts and "devils," must also have formed a large part of the landscape, especially on the borders of the rivers and estuaries. These compelled the traveller to keep to the higher ground and led to the development of trackways which would follow the ridges between adjacent valleys. These trackways have been replaced generally by main roads, one of which (between Stratton and Rock) probably became a Roman road, for Roman remains have been found near the latter place. Before discussing further the possible habits of the prehistoric inhabitants, a brief account of the earthworks and the finds of implements will be given.

THE IMPLEMENTS.

As the beautiful arrow-heads found at Dozmare* and near Cheesewring are already familiar to archæologists, and several Cornish collectors have fine specimens found on the moors, I shall not attempt to describe them here, but merely remark upon the finds for purposes of comparison with other districts in my concluding sentences.

As regards the finds in the parish of St. Clether, I may say that for three years I had found isolated specimens scattered over many square miles of country, but had not identified any locality as a possible "factory" where the flints were fashioned into shape. In September 1908, however, I visited some

* See also a paper by T. Peter on "Carn Brea Arrow-heads," *Journ. Roy. Inst. Cornwall*, Vol. XIII, p. 92.

fields west of Tregue and north of Hawksground in St. Clether, and there found hundreds of flints of all shapes and sizes, some chipped roughly into shape (Plate), others mere flakes, as well as cores from which flakes have been struck. Unbroken pieces of flint which had been carried as suitable for the production of implements were also not uncommon. Implements of remarkably good form were found: these were scrapers, arrow-heads, etc., some of which, now exhibited in the British Museum, are shewn in the photo reproduced as Plate. From the number and variety of the flakes, implements, cores, and raw material collected together at this one spot, I felt convinced that the locality was the site of their manufacture on a large scale. The presence of such a great quantity of flint naturally suggests the query as to the source of the raw material. It is certainly not locally derived, for the only flints of common occurrence in Cornwall are found in the Raised Beaches on the coast, or washed up into sheltered "gugs" or caves, as at the Gravel Gugs, Polzeath, where the shingle contains some 35 per cent of flint pebbles. Flints derived from these localities are not suitable for the manufacture of these implements, although a good many rough forms found near the sea, as at Constantine Island, south of Padstow, would appear to have been made from such local material.* The exclusion of this source for the flints makes it certain that they were brought into the county

* See also paper by Rev. D. G. Whitley already cited.

PHOTOGRAPH OF FLINT FLAKES NOW IN THE BRITISH MUSEUM, FOUND IN THE DISTRICT OF ST. CLETHER AND ST. TUDY.

SCALE, A LITTLE MORE THAN ½ LINEAR.

The first specimen on the left side of the bottom row came from St. Tudy, near the Church.
The middle specimen in the top row came from Condolden.
The rest are from St. Clether.

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TABLE SHEWING DISTRIBUTION OF IMPLEMENTS.

No.	Parish.	1″ Map.	6″ Map.	H = High / L = Low land	Locality.	Nature of Find.
			Cornwall			
1	St. Minver Lowlands	336	25 N.W.	L	South of Dinham House	Piercer and flakes
2	St. Minver Highlands	336	18 N.E.	H	Pentire Head	Flaking instrument (slate) and scrapers
3	St. Mabyn	336	26 N.W.	H	Colesent	Knife similar to one found at
4	St. Mabyn	336	26 N.W.	H	Near St. Mabyn Church	Scrapers
5	St. Tudy	336	20 S.W.	H	West of village	Scrapers
6	Lanteglos	336	14 S.W.	H	Near Castle Goff	Long flake with sharp edge and blunt tip
7	Michaelstow	336	20 N.W.	H	Helsbury Castle	Flakes common in fields
8	Tintagel	322	14 N.E.	H	Condolden	Rough arrow-head
9	Tintagel	322	10 S.W.	H	Trenalebury	Flakes and scrapers
10	Otterham	322	11 N.W.	H	Tresparrett Down	Flakes and scrapers
11	Warbstow	322	11 N.E.	H	Warbstow Bury	Scraper
12	St. Clether	336	15 S.E.	H	S.W. of Treboy	Abundance of forms (see below)
13	Lewannick	337	16 S.W.	H	Near Tinneyhall	Celt and numerous arrow-heads and scrapers (slate)

Except in the cases specially mentioned, the implements and flakes are made of flint.

from another district. It is not at all impossible as has been suggested elsewhere, that this locality was in Eastern Devonshire, where flint-bearing gravels are found at Haldon, whence the material may have been carried by traders and exchanged or bartered for other commodities.

In connection with the finds in St. Minver parish it may be well to record that while building the Wesleyan Chapel, near Pityme, the workmen, in digging out sand for the foundations, came across a "Celtic" cemetery, consisting for the most part of slate cists, which contained, according to my informant, several skeletons. All of these were again buried in the sand, and no record of them was kept.

Again, on the south side of the road in front of St. Endellion Church is another large cemetery where slate cists similar to those at Harlyn Bay have been dug up in plenty. I saw one of the cists dug up, but it was empty. Others, I am told contained skeletons which were laid out in crouching postures.

The object described in the list as a flaking instrument is made of very hard slate, and is spindle shaped. It is worn at the end and scratched on the sides as though it had suffered from use. Similar objects are found near Wilsey Down, but as the specimens were not collected, I have refrained from mentioning them in the list. These consist of the local hard grit, and several had been in use for some time. Dr. Flett tells me that he discovered

similar objects associated with partially made flint implements at several localities in the Lizard district, and these are composed of hornblende-schist and granulite-gneiss, but are found on parts of the plateau built up of serpentine. He tells me, further, that they are water-worn, and probably derived from the beach from whence the flints used in the manufacture of the implements at these workshops were also derived.

EARTHWORKS.

We may now consider the camps, rounds, and earthworks of North Cornwall and their position with regard to hills and rivers. We may commence with remarking on the singular absence of any earthworks on the great granite moorland known as Bodmin Moor, and the abundant remains of hut-circles, stone-circles, and barrows. If the one-inch map 336 (Camelford) be taken, it will be observed that the earthworks marked thereon and named "castles" and "camps" are not only confined to the lowlands, but command the main roads and the valleys of the rivers Camel and Alan. Thus, commencing on the north, there is Castle Goff, at Lanteglos; Helsbury Castle (Michaelstow); Pengenna Camp, on the Alan, in St. Teath; then a wide stretch of country in St. Tudy and St. Mabyn without any fortified positions, until the River Camel bends back upon itself near Helland, where four large earthworks command the district, the largest but one being in Dunmeer Wood and the largest at

Pencarrow. The famous Killibury Rounds dominates not only the main road between the north and south, but also the estuary of the Camel. Dameliock, famous in Arthurian legends, is placed on another main trackway, which possibly became a Roman road. On the south of the moor, between Helland and St. Neot, are several large camps, as at Cardinham, Bury Castle, and Bury Down Camp.

In sheet 322 (Boscastle), near Tintagel, Trenalebury commands the approach to Tintagel and Bossiney, while a camp at Cargurra guards the road between Bude and Boscastle.

From the list of implements given above, and bearing in mind the discoveries at Dozmare Pool, it will be seen that for the most part they were found on high land near old trackways.

GENERAL CONCLUSIONS.

We are now in a position to discuss the meaning of the differences of the flints and earthworks found respectively on the high moors and on the coastal lands, and may recapitulate as follows:—On the moors there is an absence of camps, castles, or defenced places, but abundance of arrow-heads, slingstones and the like. On the coastal lands are numerous camps and castles placed in strategical positions commanding main trackways and protecting intervening districts from marauders; while implements, such as scrapers, knives, and flakes, are mainly such as could be used in peaceful pursuits. From a consideration of these facts, it seems not

improbable that, if we may assume these peoples to be contemporaneous, the habits of the moorland folk differed from those who occupied the coastlands. The inhabitants of the moors being given to hunting, raiding, and stealing the herds of their neighbours, invaded the lowlands by way of the tracks which followed the main ridges. Such raids necessitated joint action for mutual protection on the part of the lowlanders, and the provision of defenced positions for the protection of their women, children, and cattle. This supposition would account for the position of the several encampments, and there is much probability that the moorlanders were an aggressive people, while the more genial environment of the lowlands would promote pastoral habits tending to soften the nature of their inhabitants.

In conclusion, I must say that these views are put forth as tentative suggestions, and are not considered to be fully borne out by the evidences obtained, and presented in this paper.

THE APPLICATION OF SO-CALLED "RARE" METALS TO MODERN COMMERCIAL USE.

By F. J. STEPHENS, F.G.S., M.I.M.M., M.I.M.E.

One of the most interesting features in connection with the manufacture of steel nowadays is the growing employment of various little-known minerals, which, when alloyed in certain proportions with steel, introduce new qualities or greatly intensify such properties as are necessary to obtain high-class results.

It has often happened in the history of mining that different minerals, which in one generation have been of little commercial use, have within a comparatively few years become valuable, and, from being a mere waste product, are sought after diligently, and mined sometimes to the exclusion of the minerals which in an earlier age were the valuable ores.

We have several examples of this state of affairs in Cornwall, especially in connection with tin and copper ores, which have frequently replaced one another in premier importance.

Thus, although tin-mining is of great antiquity in

UNCOMMON MINERALS USED IN STEEL MANUFACTURE.

The requirements of modern trade have quite revolutionized the manufacture of steel for many purposes. Here hardness or toughness are no longer the only points required in practice, and a special variety of steel is sought for for almost every purpose—for high-speed, self-hardening tool steel, for structural purposes, for steel plates for ship-building, armour plates, and ordnance.

A great demand has therefore been created for alloy steels—that is to say, steels in which various percentages of other metals are introduced, usually by means of what are known as the ferro-alloys.

The use of manganese ores in connection with the steel trade and in foundry practice has been established for many years, and nickel and tungsten steels have also grown to importance.

Besides these comparatively well-known auxiliaries of the steel trade, some minerals which are still commonly considered rare minerals have been introduced with great success. Amongst these are the ores of chromium, molybdenum, vanadium, uranium, cobalt, and titanium. All these ores have been used, and the resulting alloys have produced steels of wonderful quality.

Although these ores have been considered rare in occurrence, yet as search is made for them in various regions they are found to be fairly evenly distributed over the world.

Many of the substances from which these metals are produced are of a refractory nature, and in former years were hard to smelt.

The great strides in electro-furnace smelting, the introduction of the alumino-thermic processes and others have enabled these minerals to be treated as easily as commoner ores.

Manganese, nickel, and chrome steels have been used in steel-making for many years, tungsten has been experimented with for a long series of years, but the other alloys are comparatively very recent.

Manganese ores were and are still used in chemical works for pigments and bleaching purposes. The great value of manganese to the steel trade was first established by the late Mr. George Blackwell, of Liverpool. Nearly all the ores used by him some forty years ago came from Devon and Cornwall.

Manganese steel castings have a high value in mining practice for crusher jaws, roll shells, etc., but the steel is not easily tooled in the turning-lathe.

The expansion of the manganese ore trade has been gradual, until there are now large and steady imports into Great Britain from many parts of the world.

The great centre of the manganese steel trade is now at Sheffield, but nearly all the ore comes to Liverpool, where Messrs. Blackwell, who are pioneers in this business, make large quantities of all these ferro-alloys. Fifty per cent manganese

ores are now worth about £16 a ton. The bulk of the ores come from India, Brazil, and the Caucasus, but there is reason to suppose that the ores exist in some quantity still in the West of England.

The tungsten and molybdenum ores are used largely in the manufacture of self-hardening rapid tool steel.

Of late, however, the value of the latter alloys has been proved in a remarkable degree for the manufacture of ordnance and armour-plate.

Tungsten steels are exceedingly hard, but somewhat brittle, and they are not impaired by heat, as is the case with ordinary carbon steels. They require very careful attention in the manufacture, as an excess of carbon in a batch of tungsten steel ruins it. Consequently there is still a certain amount of prejudice against its use amongst some makers.

Very pure ores of tungsten come from Australia and Portugal. The range of price is great—the purer ores fetching better figures than those which contain even only a small percentage of tin or sulphur.

The supply seems to increase with the demand, and it is now obtained from several parts of the world.

Scheelite or tungstate of calcium is a heavy white mineral which is valued by alloy-makers, and is probably more abundant in Cornwall than is commonly supposed.

The commonest ore containing chromium is

chromite, or chrome iron ore. Its use in hard-steel making is fairly general. Chrome and nickel steel compounds make a tough uniform material of very evenly distributed quality. Nickel has the quality of adding not only hardness, but great tensile strength to steel, and, in combination with such metals as molybdenum and vanadium, intensifies the good qualities possessed by these.

The use of double and even treble ferro-alloys, such as chrome vanadium nickel, is becoming, therefore, pretty general in the latest hard-steel practice.

Nickel ores are of course abundant, the bulk coming from New Caledonia and Canada, while chrome ores are mined in Asia Minor, Turkey, and Greece.

Fifty per cent chrome ores are worth about £4 a ton. Messrs. Blackwell ship from their own mines in Greece to Liverpool.

Over 120,000 tons of chrome ores are mined annually.

Molybdenum and vanadium are two of the most valuable metals yet used in the composition of hard steels. If only sufficient quantity of ores can be discovered, they are likely to reach a great development. Whereas, however, the ores detailed are sufficiently abundant, the metals I have now to deal with are considered by most people, with the exception of titanium, to belong to the category of the "rare minerals."

Ores of molybdenum, however, although still scarce, are turning up from many parts of the

world. The author has been especially associated with this mineral for several years in the service of Messrs. Blackwell and others, and has inspected deposits of molybdenum-carrying ores in Norway, Sweden, France, Portugal, Newfoundland, Canada, and the U.S.A., as well as in the United Kingdom. He can therefore claim an extensive knowledge of the minerals.

Prior to 1900, molybdenite, which is the chief commercial ore of molybdenum, was used only as a pigment and in chemical works.

The late Mr. George Blackwell and his son, Mr. Harold Blackwell, pioneers in so many of the steel-hardening metals, have consistently experimented with the ores and metal until its usefulness cannot be gainsaid.

Molybdenum steel is of very high tensile strength, and is specially adapted for wire-drawing and the manufacture of high-grade steel ropes. It has many advantages over tungsten steel, and tools made from it retain a cutting edge much longer. It requires less than half the quantity of alloy to produce the same effect as tungsten in this respect, and in the matter of steel plate, for armour-plate and ordnance generally, it is a very formidable rival to nickel steel and nickel chrome steel.

In the case of heavy forgings, molybdenite steel has been found extremely valuable, and especially for large crank-shafts and propeller-shafts. An extremely tough and armour-piercing shell has been made from this steel, and in recent experi-

ments projectile and armour-plate made from it gave the highest results. It is, in fact, one of the most valuable metal alloys ever placed at the disposal of the steel-maker.

The ores of molybdenum of commercial value are molybdenite or sulphide of molybdenum, and wulfenite or molybdate of lead. Molybdenite is a silvery mineral, one of the softest. It resembles graphite, but has a bluish appearance readily distinguishable from the dead colour of graphite. The metal is of a silvery appearance, but is extremely hard and of a high-fusion point.

Ores are produced from all parts of the world, but the most important producers hitherto have been in Norway and Australia.

Molybdenite concentrates running 95 per cent are worth about £150 a ton. The mineral occurs often in granitic regions, sometimes disseminated sparsely throughout the rock itself, as in Connemara, but more usually in quartz veins in granite rocks, and sometimes in schistose rocks.

Molybdenite has a peculiar affinity for copper sulphide, and has frequently been found in copper lodes.

Until recently this has rendered the mineral difficult to concentrate cleanly, as the copper and molybdenum sulphides are as near as possible of the same specific gravity.

As a result of exhaustive experiments made recently it is, however, now claimed that the two minerals can be effectively separated; therefore molybdenite ores, when intimately associated with

copper ores, need not in the future be neglected on that account.

Copper pyrites, when left in concentrates of molybdenite in a higher proportion than 3 per cent, act deleteriously in the later smelting operations.

The mineral has been found associated with silver ores, and the author has specimens of molybdenite from many different rock formations, including dolomite and serpentine.

Although found fairly abundantly in the west of Ireland, Cumberland, and in the Highlands, so far molybdenite has occurred only associated with other ores in a few places in Cornwall, as enumerated in Mr. Collins's *Mineralogy*.

I see no particular reason, however, why molybdenite ores should not be found in Cornwall as freely as in other copper regions. At the present time ores running less than 1 per cent MOS_2 are being worked.

Vanadium ores are at the present time expensive; ores containing as little as 2 per cent vanadic acid can, however, be treated profitably at Liverpool in the works of the International Vanadium Company.

The particular advantages compared to the other ferro-alloys of ferro-vanadium when added to steel lie in the fact that a very small quantity (less than 2 per cent in some cases) makes a wonderfully elastic, strong, and ductile steel.

The cost is very high, and hitherto one great objection to vanadium steel was that the alloys made by the alumino-thermit process were not constant.

The International Vanadium Company of Liverpool, a company formed by Messrs. Blackwell a year ago, are now making ferro-vanadium from ores containing as low as $1\frac{3}{4}$ per cent vanadic acid, by a process which makes an absolutely constant alloy.

Vanadium is produced from the vanadates of copper, lead, and iron, and from a uranium-vanadium mineral called carnotite, which is found largely in Colorado and Utah. Vanadates of copper and lead come from Peru, and the Chilian coals contain a quantity of vanadium.

There is a ready market for even low-grade ores, and these ores fetch good prices.

As in the case of uranium and molybdenite, vanadium ores have occurred in Cornwall, and it is very likely that vanadates of lead and copper occur in the old copper and lead mining districts.

A very large deposit of pitchblende was discovered in Norway last year, and there are plenty of ores containing uranium in the United States.

Uranium alloys have been experimented with in steel-making, and are found to be of considerable value, having much the same effects as vanadium.

Of course uranium ores containing radium at the present time are very valuable, but there are many ores containing as high, perhaps, as 5 per cent uranium which may not contain radium, and are therefore applicable to steel-making.

A good many of the thorite group of ores contain

as high as 10 per cent uranium, and samarskite, a curious mineral resembling obsidian, carries a good percentage of uranium.

If anything like a considerable output of uranium ores could be maintained, they no doubt would be readily used in steel-making.

The same objection, prohibitive price, applies to the use of cobalt, which is supposed to be quite a rare mineral.

Nevertheless, cobalt is turning up in fair abundance in many parts of the world. It is valuable as an alloy, having much the same properties as nickel; that is to say, it acts as an excellent medium in introducing other alloys, and makes steels harder and more homogeneous.

Cobalt ores have been found in Cornwall in small quantity, and they have occurred in late years in many places abroad.

Another mineral has been tried in steel-making for many years with very varying results, and has now been definitely recognized as possessing valuable properties.

I refer to the ores producing titanium or titanic acid, such as rutile, titaniferous iron ores, etc. Ferro-titanium alloys have use both in foundry practice for ordinary cast irons and steels, and it acts in a very similar manner to manganese, on account of its affinity for oxygen.

Ferro-titanium introduced into castings is said to give greater transverse strength and a greater density. It also takes a harder chill, and is thus

often used for the cheaper crusher jaws and roll shells and for cast car-wheels.

The following table shows the particular advantages of the minerals and their metal alloys in steel-making, and approximately their market values :—

In introducing my subject, I have referred to the manner in which minerals at one time neglected have in another age become of value and been sought after. Although the minerals I have enumerated have not at any time been sought after purposely in the west of England, it does not follow that they may not hereafter be found in some abundance.

Those of us who, in the active pursuit of the mining profession leave our native county, often for years at a time, have rarely much opportunity, except in after life, to carry out lengthy investigations; but in these days when mineralogy is a familiar science to many of those who stay at home, the foregoing notes on minerals not ordinarily recognized as of commercial value may perhaps lead to a regular search through the long-abandoned "dumps" of some of our older mines.

Metal.	Ores.	Ferro-alloys.	Approximate percentage of metal used in steel-making.	Approximate tonnage used annually of ores and metals.	Properties of alloy-steel.	Approximate prices of metal or minerals.
Nickel.	Silicate of nickel, nickel pyrites.	Nickel chrome, ferro-nickel, etc.		12 to 14,000 tons of metal.	Used chiefly in combination with other alloys, mostly with chromium, etc. Has the property of intensifying the effects of other alloys.	Pure nickel about £150 a ton.
Cobalt.	Various ores.	Same properties as nickel.			Experimental.	Cobalt oxide about £400 a ton.
Manganese.	Pyrolusite, psilomenese, etc.	Ferro-manganese, etc.	7 % to 30 %.	Many thousands of tons mineral used annually.	Has the property of de-oxidizing. Hardens and strengthens steel. In castings gives a hard chill, which is difficult to tool. Generally improves and toughens all irons and steels.	50 % manganese ores approximately £4 a ton.
Titanium.	Titaniferous iron ores, rutile.	Ferro-titanium, etc.		Plenty available.	Similar to manganese.	Very cheap.
Chromium.	Chrome iron ore, chromite.	Ferro-chrome, ferro-chrome nickel, molybdenum chrome.	From 1 % to 2 % chromium.	70,000 tons chrome ores.	Makes extremely tough homogeneous steel. Very hard. In conjunction with nickel, used for armour-plate.	£3 10s. a ton 50 % chrome ores.
Tungsten.	Wolfram, hubnerite, scheelite.	Ferro-tungsten, tungsten nickel, tungsten chrome.	From 5 % tungsten and upwards.	4 to 5000 tons annually.	Self-hardening steels for high-speed tools. Armour-plate.	Variable. Pure tungsten ores at present over £100 a ton.
Molybdenum.	Molybdenite, wulfenite, etc.	Ferro-molybdenum, molybdenum chrome, molybdenum nickel.	About 2 % molybdenum introduced into plates.	Moderate supply. Large demand.	Increases the elasticity and toughness and tensile strength. Elongates immensely. Excellent for rope-wire, armour-plate, ordnance, etc.	95 % molybdenite concentrates worth about £140 a ton.
Vanadium.	Vanadates of lead, copper, and iron, carnotite, etc.	Ferro-vanadium.	Less than 1 %.	Increasing quantities.	Same properties as molybdenum, but not in such a marked degree.	Very high prices. Metal very costly.
Uranium.	Pitchblende, samarskite, uranites, etc.	Ferro-uranium.	Similar properties to vanadium.		At present too costly to come into practical use.	

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H. Carne, Penzance.
P. T. Chirgwin, Penzance.
The Viscount Clifden, Lanhydrock, Bodmin.
W. Colenso, Penzance.
W. Colenso, Jr., Penzance.
H. E. Cook, Rose Cottage, Par.
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J. D. Enys, F.G.S., Enys, Penryn.
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S. Fawns, F.G.S., 16 Sussex Mansions, S. Kensington, S.W.
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F. G. Brook Fox, F.G.S., Porth Navas, Penryn.
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G. Pearce, Hayle.
W. C. Pendarves, Pendarves, Camborne.
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John Symons, Penzance.
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J. Westlake, K.C., 3 Chelsea Embankment, S.W.
J. C. Williams, Caerhayes Castle, St. Austell.

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The Secretary requests the favour of his being informed of any inaccuracies in the foregoing lists.

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Since the Foundation in 1814.

1814–1839.	DAVIES GILBERT, ESQ., M.P., F.R.S., etc.
1840–1856.	SIR CHARLES LEMON, F.R.S., etc.
1857–1862.	AUGUSTUS SMITH, ESQ.
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1868–1870.	H. SEYMOUR TREMENHEERE, ESQ., F.G.S.
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1880–1881.	SIR A. P. VIVIAN.
1881–1882.	LORD COURTNEY OF PENWITH.
1883–1890.	SIR WARINGTON SMYTH, F.R.S., etc.
1891–1892.	LORD ST. LEVAN.
1893–1894.	HOWARD FOX, ESQ., F.G.S.
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1911–1912.	J. H. COLLINS, F.G.S.

THE

ANNIVERSARY ADDRESS OF THE PRESIDENT,

J. H. COLLINS, ESQ., F.G.S.

To the General Meeting, October 31st, 1911.

LADIES AND GENTLEMEN,—I have often thought it would be a work well worth the doing to compare the state of Geological, Mineralogical, and Mining knowledge, and the condition of the miner in our two Western Counties a hundred years ago when this Society was founded, with their corresponding state and condition to-day. It is, however, much too large a task for me to attempt, at any rate at present. But restricting my remarks to mining alone, I may say that, although the population was only about two-thirds of what it is at present, there were then in operation more than seventy mines, chiefly of copper, but many producing large quantities of tin; also a few lead mines; and that the whole annual value of the ores produced was somewhere near to one million sterling. Many of these mines were equipped with large and powerful pumping engines, while the tin mines had stamping mills operated by water power.* The production of metallic ores other than those already mentioned was quite insignificant, and the same may be said of china clay and china stone.

Of the condition and progress of mining during the past fifty years I can speak with more or less of personal knowledge and in considerable detail. My direct connection with the industry began in the year 1868, when I succeeded the late Sir Clement (then Dr.) Le Neve Foster as Lecturer and Assistant Secretary to

* The first to be operated by steam power is said to have been erected at Wheal Fanny in 1813.

Mr. Robert Hunt's Miners' Association of Cornwall and Devon. Strictly speaking, therefore, my personal knowledge of the West Country Mining Industry only covers about forty-four years, but as I had been interested in the subject for several years previously, I can with very little retrospect fairly speak of fifty years. In the year 1861, mining in the West of England had about reached its zenith. The production of tin ore, which had been going on for twenty centuries or more, was approaching its maximum (which it reached in 1871); that of copper ore, then nearly four centuries old, had a little passed its maximum (which was in 1856); lead mining, which was much older, was still a very important industry, while not inconsiderable quantities of zinc ore, iron ore, iron pyrites, arsenic ore, and sundries contributed, according to Mr. Robert Hunt's official statistics, to a total of no less than 248,392 tons of ore, worth £2,055,253.*

If we add in sundry parcels of manganese wolfram, and other ores which are not included in the returns quoted, also 82,000 tons of china clay and china stone, which could hardly have been worth less than £1 per ton at that time, we reach the grand totals of about 330,000 tons of minerals worth about £2,150,000.

* The details for twelve months ending September 29th, 1860, some of the returns being a little conflicting, and some values estimated only, are as follows:—

	Cornwall.		Devon.		Total.	
	Quantities tons.	Value.	Quantities tons.	Value.	Quantities tons.	Value.
		£		£		£
Copper Ore	143,789	884,982	35,283	186,082	179,072	1,071,064
Tin Ore	10,255	798,209	175	13,951	10,430	812,160
Lead Ore	6,401	89,614	3,019	42,266	9,420	131,880
Zinc Ore	4,772	10,870	217	639	4,989	11,509
Iron Ore	22,413	6,088	—	—	22,413	6,088
Iron Pyrites	17,369	16,560	3,432	1,516	20,801	18,076
Arsenic Ore	515	943	30	56	545	999
Nickel Ore	7	255	—	—	7	255
Fluor Spar	81	86	—	—	81	86
Gozzan, etc.	324	409	—	—	324	409
Silver Ore	125	2,365	—	—	125	2,365
Argent. Copper	185	362	—	—	185	362
	206,236	1,810,743	42,156	244,510	248,392	2,055,253

The number of mines producing ores of various kinds is given as 362, probably representing about 300 individual mines.*

The value of 16,923 tons of metallic minerals produced in 1909 was £692,660, and of 790,335 tons of china clay, mica, clay, and china stone was £514,330, or together 807,257 tons worth £1,206,990.†

* 543 names are given in various lists, but many of these had been closed down and others were mere prospects.

† The details of metallic minerals produced in the year 1909 are as under:

	Cornwall.		Devon.		Total.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.
		£		£		£
Arsenic	1,832	16,066	1,048	12,121	2,880	28,187
do. Pyrites	—	—	93	150	93	150
Copper Ore	1,580	5,522	18 443	495 2,200	2,041	8,217
Iron Ore	43	248	676	193	719	441
Ochre	—	—	1,728	3,565	1,728	3,565
Tin Ore	8,166	607,502	123	9,874	8,289	617,376
Uranium Ore	6	640	—	—	6	640
Wolfram	332	28,295	11	845	343	29,140
Zinc Ore	824	4,944	—	—	824	4,944
Totals	12,783	663,217	4,140	29,443	16,923	692,660

In a few cases the figures given above are estimated only, from lack of official returns.

China Clay, etc., Produced during 1909.

	Cornwall.		Devon.		Total.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.
		£		£		£
China Clay.	639,939	420,665	70,441	59,088	710,380	479,753
Mica Clay	16,632	5,108	7,295	3,117	23,927	8,225
China Stone	56,028	26,352	—	—	56,028	26,352
	712.599	452,125	77,736	62,205	790,335	514,330

I do not here include the quantities and the values of the igneous rocks, pottery clays, etc., as they were not recorded in 1860.

From the details given it will be seen that very notable changes have taken place during the fifty years. The value of the copper ore produced falls from over one million sterling to a mere £8000, and that of lead ore from £155,000 to nothing at all, while the tin ore is less valuable by nearly 25 per cent. On the other hand, arsenic ores show a large increase, and wolfram appears as a considerable asset, while the value of the china clay has increased nearly tenfold.

Besides the great changes in the character of the minerals raised, we cannot but observe with regret the almost entire cessation of mining in so many of the once famous mining districts. On this subject more will be found in the fourteenth volume of the Society's *Transactions* when it appears a few months hence.

The early sixties and seventies were times of transition in mining methods and mining appliances. The man engine, the employment of which had been greatly assisted a quarter of a century earlier by substantial prizes offered by the Royal Cornwall Polytechnic Society, was still in use in a dozen of the principal mines; wire ropes and skips were gradually replacing chain and kibble,* while rock-boring machines, thanks to the initiation of my predecessor, had already been practically tested in several parts of Cornwall in the year 1866. At first, however, the machines were operated by steam, and I well remember the working of Doering's machine, so operated in Tincroft Mine in the year 1868. Of course, no extensive use underground was possible until air-driven machines were introduced, although steam-driven machines were used in the open air for many years thereafter, and in particular at Rock Hill, near St. Austell, in the year 1874. Once introduced, however, the air-driven machines made their way rapidly at home, and still more rapidly abroad, wherever, indeed, large excavations had to be made in hard ground, or where speed of driving was essential.

The large numbers of picturesquely clad hymn-singing balmaidens, who were formerly to be seen in most of the mines,

* Kibble-winding was, however, still common even in such deep mines as Cook's Kitchen and Dolcoath thirty years ago.

have almost entirely disappeared, and with them the "rack," "cobbing-hammer," "bucking-hammer," and "hand" or "brake-staff" "jig." All of these, together with the wooden-shafted stamp,* were still at work thirty years ago, while the stone-breaker, the California and air-cushion or Pneumatic Stamp, the various forms of pulverizers or tube-mills, the Frue and Luhrig Vanners, the Wilfley and Buss tables, the self-acting and round slime frames, the air-compressor, and many other contrivances which are now looked upon as essentials in most well-provided mines, were some just being introduced, and others yet in the future. When one compares the present condition of Cornish mining with its condition in those days, it is obvious that a great revolution has taken place in its machinery and appliances.

In mining proper, apart from machine drilling and the use of high explosives, which are not everywhere applicable with advantage, there has been no great advance during the fifty years. Somewhat greater depths have been attained in a few instances, and notably at Dolcoath, but Cornwall is still far behind several other mining regions in this respect. We are now more impressed than heretofore with the advantages afforded by good shafts, good underground roads, and good surface transport; the tramroad and tram-wagon have largely displaced the wheelbarrow; underground ore-bins, once so rare, are now becoming common; but in the main, our system of underground mining was so good even a century ago that there has not been very much room for improvement. Still, I venture to predict that in the immediate future more vertical shafts will be sunk and provided with cages, that levels will be driven farther apart, that there will be a great deal more cross-cutting, and that our underground tramroads will be better constructed, so that "three men at a wagon" will be no more heard of.

The difference between "to-day" and "yesterday" is seen in the fact that no rock-drills have ever been employed in the great mining parishes of Gwennap and Breage, several of whose mines were still at work a generation ago, while at present all the great mines of the neighbouring parishes of Camborne and Illogan

* These stamps may still be seen at work in the valley below the Carclaze Mine on ore raised from the great open-work at Minear Downs.

depend very largely upon these machines; not because they break the ground more cheaply (for it is well known that such is not the case; moreover, in narrow lodes they do not even break the ground more advantageously, for the "pay-streak" inevitably becomes much contaminated with barren "country"), but because they open the ground more speedily it becomes more and more necessary to employ them. One good effect of their employment has been the enlargement of the main drifts and consequent improved ventilation, and this too has been greatly assisted by the large amount of cool exhaust air set free by the machines. The greater number of machine-drills hitherto have been employed in sinking, rising, or drifting, but there is a growing tendency to employ them in stoping also. The small hammer-drill has not made much way with us as yet—it is hard to say why this is so.

Fifty years ago much gunpowder was still used in the mines, and the use of safety fuse was only just coming in; to-day, after many experiments with compressed powder and other such compounds, and after nitro-glycerine had been tried and given up because of its danger, only such "high explosives" as dynamite, gelignite and the like are used even in ground where black powder would be sufficiently strong. These high explosives only came into use after much experimenting, by the Royal Cornwall Polytechnic Society in particular, but they have proved themselves very serviceable, especially in hard ground, and they are also found to be much safer in use than the old black powder.

Great improvements have been effected in the machines used for compressing the air employed in working the machine-drills; compound engines compressing the air in successive stages are now often employed in the larger mines.

It is generally admitted that up to the present the Cornish system of pumping,—the rods being operated by a simple vertical engine, and single acting in the case of large pumps,—holds the field, especially where sinking is in progress. A Davey compound engine has been employed for years past in pumping at the Basset Mines, using the ordinary Cornish system of plunger sets.

Some attempts have been made to operate Cornish pumps by means of electrical appliances, but so far without much success.

Electrically-driven ram-pumps have been more successful, and the whole county is now watching with interest the great installation at William's Shaft in Dolcoath. The employment of centrifugal pumps operated by electricity, though in some respects successful, has not yet established itself in any important mine.

The use of electricity is spreading in the Cornish mines apart from pumping; at East Pool it has long been employed for surface traction, the mill being a mile or more away from the mine. At South Crofty it is employed for operating the rock-breaker and the stamp mill; in several mines it supplies power to work pulverizers, buddles, and other dressing machines, and in this direction, as also in electric lighting, there is a large field for extension. The Wetherill electro-magnetic separator is employed in several of the mines for separating wolfram from the tin-concentrates, and a simpler form of separator has been successfully used for removing magnetic and specular iron oxides.

There has been great improvement in the engines used for winding during the past few years. It no longer takes forty minutes to raise a kibble of stuff from the bottom of the deeper mines as it did even thirty years ago at Cook's Kitchen; skips running between guides are now common, cages bringing the ore-wagons direct to the surface are employed in several mines, and the men are mostly brought up from below in shaft-gigs or special skips, so that the man-engine, once so great a boon and so common, can now only be seen in operation in the Levant Mine. For modern winding wire-ropes are universally used, and are practically indispensable. Accidents from its use are indeed exceedingly rare. Double horizontal winding engines are now commonly employed, often of the compound type and provided with condensers. Mr. Morgan's traversing engine, erected some years since for hoisting from William's Shaft at Dolcoath, is doing good work, but so far no proposals seem to have been made for using this remarkable engine anywhere else.

For signalling in shafts the old "knocker line" is still in use and has its advantages, although electrical signalling is gradually coming into use. Indicators for the guidance of the engine-man

are of course placed in the engine-houses in every case where men are raised and in most other cases; overwinding is an extremely rare occurrence, such is the carefulness of the engine-men. The telephone was introduced in Wheal Eliza by Dr. Le Neve Foster many years ago for signalling from below, but it did not "catch on." It is, of course, used for ordinary business purpose in several of the mines.

The steam-boilers used in Cornwall are still mostly of the Cornish or Lancashire type and work at comparatively low pressures. The number of these boilers working at 60 lbs. to the square inch is not very great, while boilers working at 100 lbs. or more could almost be counted on the fingers. Multitubular boilers, portable or semi-portable, are used in some instances, and particularly for winding engines; the difficulty in getting sufficiently pure water prevents their more extended use. Internal combustion engines using "suction gas" are used in some instances for pumping, winding, crushing, etc., as also for operating centrifugal pumps in alluvial "dredging."

The ore treated now is almost exclusively tin, copper ores being rare, while the working of lead and zinc ores has practically ceased. Many improvements have been introduced in the treatment of the ore.

The first crushing is generally done by stonebreakers of the Blake type followed by stamps of the Cornish, California, or "Pneumatic" type, the "rows" or "crazes" being finally reduced by some form of pulverizer.

Self-feeders have not yet been used for the Cornish stamps, but they are always employed with the other types of stamps named.

At Dolcoath powerful batteries of all three types might have been seen regularly at work a short time since; the small Californian battery is still at work there, but quite recently the Cornish have been superseded by a powerful battery of Holman's air-cushion or pneumatic stamps.

In many of the mines some hand selection of the ore before stamping is practised—both below and above ground; at South Crofty the roughly crushed ore falls on travelling picking-belts

which allows of a better selection. But it must be admitted that in general tin ores are not so suitable for this treatment as are ores of copper, lead, or zinc.

Twenty years ago a very excellent system of hand-selection was in operation at Devon Consols, near Tavistock. The fines were screened from the rough ore for jigging, and the roughs, having been washed clean, were spalled with heavy sledges. The spalled product was then most skilfully selected by boys and women into classes as follows, each kind being thrown into its proper box or wagon and removed for subsequent treatment, as under :—

1. Best copper ore—only needing to be run through the crusher when it was ready for sampling and sale.

2. Best arsenic ore—for crushing and subsequent calcination.

3. Dredge copper ore—for crushing and jigging, after which it was added to the sale piles.

4. Dredge arsenic ore—for crushing, jigging, and calcination.

5. Waste rock—for the dump.

Had the ores contained tin or wolfram, as is sometimes the case, the selection would have been still more complicated, and would have called for still more mineralogical knowledge on the part of the workers.

For dressing the crushed ore, while buddles are still very generally used at some stages, Wilfley or Buss tables or Frue Vanners are employed in most of the larger mines. Hydraulic separators are mostly used to remove the slimes before feeding the pulp to the Wilfley and Buss tables, but in the case of the Frue Vanner the slimes are generally removed for separate treatment at a later stage.

For slime treatment there is still nothing better known than the dead-frame, the ordinary slime table, or the Acme table. The old-fashioned swinging rack for cleaning slime has practically disappeared, though it had some notable merits.

Most tin-concentrates need calcination before they can be cleaned for market. In many of the smaller mines the old

reverberatory oven is still in use, but in the larger mines Brunton or Oxland revolving calciners are always employed.

The calcination of tin ores produces in some mines large quantities of "arsenic soot," which at one time valueless or worse is now an important by-product. It is handled by the ton as freely as sand and apparently with equal impunity, for cases of arsenical poisoning are more rare in Cornwall than in our large towns. Another important by-product is wolfram, which at one time was merely a deleterious component of the dressed tin, but is now profitably extracted at many of the mines, and in particular at East Pool, South Crofty, and Carn Brea. At these mines, too, some tin wolfram products are, at one stage in the cleaning operations, "pickled" with dilute acid (aided by jets of steam at East Pool), in order to remove certain highly magnetic iron oxide components which seriously interfere with the operations of the magnetic separator. A similar "pickling" has long been recommended and occasionally used for the removal of copper from calcined tin ores.

At Tywarnhaile and also at Dolcoath attempts have been made to employ the Elmore oil process for the concentration of low-grade copper ores. This process, it is thought, may yet have a more extended application in the county, but so far it can hardly be said to have met with great success.

For many years past large quantities of tin concentrates have been recovered from the beds of the Red River and other streams which receive the wastes of our mines, by means of ingenious and extensive semi-automatic appliances owned and worked by companies of "streamers." Fifty years ago the quantities so recovered were small, but during the past thirty years the industry has assumed very large proportions, so that from 1881 to 1909 the total quantity of concentrates so produced has been no less than 31,548 tons, which sold for £1,310,149.*

* In this connection reference may be made to the operations of the company which is now so successfully treating the ancient piles of refuse from the Carn Brea and Tincroft mines under the able direction of Mr. Richards.

These operations have been called "tin-streaming," but they are in no way related to the tin-streaming operations which were for so many centuries carried on in working our ancient river and moor stanniferous gravels, and which, having been the earliest of all, continued to be of much importance up to about 1850.

This "tin ground" of former days was thought to be exhausted long ago, except perhaps at Restronguet in the Lower Carnon Valley, where about forty years ago an extensive engineering operation was undertaken to open up a considerable area of detritals which lay beneath the sea. But the recent operations at Goss Moor, Redmoor, and a few other places where centrifugal suction or bucket dredges have been set to work on a considerable scale, have shown that payable gravels exist still over large areas. The successful re-treatment of the ancient waste-heaps of Carn Brea and Tincroft will probably be followed up by similar enterprises in other districts.

The condition of the working miner has been very greatly improved in the half century under review. He does less work for more money under better working conditions, and with much better chances of advancement. The wages of tutwork and owner's account men fifty years ago probably did not exceed on an average 2s. 6d. for eight hours' work. Tributers occasionally earned a great deal, but they took a certain amount of risk, and they were content with a subsist or minimum wage of about the same amount. There are few underground men now who work more than forty hours per week, or who earn less than 6d. per hour, while the more skilled miners not seldom earn 1s. per hour or even more.

For all this the miner has to thank legislation, philanthropy, and Imperial expansion. The first has given him free elementary education, employers' liability for all accidents, even those arising from his own neglect of precautions, and indeed those following on express disregard of the regulations made for his safety; the second has given him, almost without cost to himself, the excellent technical education which the successive mining schools and latterly the County Council has provided; the third,

by furnishing a broad field and liberal pay for the energies of the educated miner.

One result of all this which has proved decidedly disadvantageous to our mines has been the greatly lessened existence of tributing, probably the most ancient of our mining customs. Tutwork and owner's account work can be prosecuted by men who are little more than machines. The successful tributer is the experienced miner who can think as well as work, and who has initiative and the speculative spirit. Such men, particularly when they have profited by the technical education which has been placed within their reach, are the very men who have gone abroad to better themselves. And though a great many have died abroad at an early age, and a great many more have returned home to die, still enough have survived to enjoy the modest competence which they have secured from their well-paid foreign labour to encourage the cream of our mining population to "go and do likewise."

The first Mining School* was that founded at the Royal Institution of Cornwall by Sir Charles Lemon in 1838, and carried on at Truro, mainly at his expense for over two years. In 1853 the Royal Institution started the second School, but it was closed in 1858 for want of sufficient financial support. A third scheme was started by the same Institution in the same year, when the admirable system of District classes for working miners and mine agents was inaugurated by Mr. Richard Pearce, who opened a class at Pool besides giving courses of lectures at Truro, St. Agnes, St. Just, and other places. This third effort was soon merged in the larger scheme of Mr. Robert Hunt by the formation of the Miners' Association of Cornwall and Devon, which continued its work until 1884, when it was amalgamated with the Mining Institute of Cornwall. All these educational schemes had to depend upon voluntary subscriptions from individuals, or from such bodies as the Society of Arts and the City and Guilds of London Institute, with small grants in the form of

* An outline history of the early provisions made for the technical education of the west-country miner will be found in the report of the Miners' Association of Cornwall and Devon for 1872.

"payments on results," from the Science and Art Department, and consequently they were very much crippled in their efforts. But when the Cornwall County Council found itself in a position to make grants in aid of technical instruction from the "whisky-money" a new era was inaugurated, and the schools started at Redruth, Camborne, and St. Just soon began to make great strides, that at Camborne especially, liberally supported as it has been by the Basset family, soon attracted large numbers of up-country students whose payments enabled the Managers not only to pay decent salaries to its officers, but to purchase and equip the King Edward Mine for the better training of its students. Now that, largely by the influence of the Institution of Mining and Metallurgy, and under the control of Mr. Fischer-Wilkinson, these three schools have been consolidated under one Board of Governors, we may expect that still better results will be secured. In particular, it is to be hoped that the old system of taking elementary instructions to the mining villages, which was so successfully carried out by Messrs. Pearce, Twite, Le Neve Foster, Collins, Kitto, Letcher, and others, will be revived and extended.

Among other notable improvements in the condition of the miner may be mentioned the universal provision of buildings for the drying of the miners' clothes, wherein warm water is always provided for washing on coming up from below. The employers' liability for injuries or accidents has also been a great boon to the men, although it has pressed hardly on some of the mines.

There has been one other notable change which has not proved altogether advantageous either to the mines or the miners. I refer to the practical disappearance of female and the great lessening of boy labour in connection with the important department of ore treatment. We have little definite information as to the numbers of women and children employed in the mines fifty years ago, but guided by the figures given by Sir Charles Lemon as quoted by De la Beche (*Rep.*, etc., pp. 621–2), and taking into account the relative mineral production of the two periods, we shall not be far wrong in estimating that 40,000 people were employed in 1861, of whom about one-third were women and children in almost equal proportions. In 1909 the number

employed, as given in the *Mineral Statistics* (which includes quarry and clay-workers as well as miners), was 16,380, of whom scarcely any were women. Of boys from 14 to 18 probably about 3000 were employed, but certainly not more.

Another change, which should be noted as having been introduced mainly by the efforts of Mr. Strauss (formerly M.P. for the Mining Division), is the extension of the ancient system of copper ore ticketing (now defunct) to the sale of tin ores.

The remarks I have made on our mining industry at such widely separated intervals are meant to be suggestive rather than exhaustive. Enough has been said however to show that the Cornish miner to-day, as in the past, is very ready to avail himself of such new methods and appliances as seem to have a reasonable prospect of success, although it must be admitted that he is rather fond of letting other people experiment for his benefit. I may refer, too, to the greater care exercised as to sanitation underground and to hospital and ambulance provision at surface, all of which have proved very advantageous to the miner.

I can only further on this occasion barely refer to the disappearance of the ancient Stannary Court, which has become merged in the County Court, and to the almost equally complete disappearance of the Cost Book Companies, which now only survive at East Pool, and Levant.

I must now conclude my somewhat lengthened remarks by performing a very pleasant duty. The Geological Re-Survey of our western mining region had been vainly called for during nearly half a century. It was undertaken by the present Director-General of the Survey, Dr. J. J. H. Teall, about ten years ago, and partly in response to an appeal from this Society. Several distinguished geologists have taken part in the work, and our good friend Mr. Clement Reid has been in charge of it almost from the commencement. Mr. Reid is not only a geologist of wide experience, he is also a palæobotanist and an antiquary. And he has had the advantage of the talented pencil of his wife in many of his researches.

Mr. Reid joined the staff of the Geological Survey in 1874. He commenced work on the devonian, triassic, liassic, and cretaceous rocks of Devon, but after a short time was transferred to Norfolk and Suffolk. The results of his work in the Eastern Counties are recorded on the published maps and in an important memoir on the geology of the country around Cromer. In the course of this work he was led to a study of the pre-glacial fauna and flora, and their relation to past changes in climate and physical geography. As the mollusca did not give satisfactory results, he turned his attention to the plants and thus commenced a long series of researches in which, by the adoption of new methods of investigation, he has thrown much light on past changes in climate and on the origin of the British flora.

From the drifts and pre-glacial deposits of the Eastern Counties he moved to the oolite and lias of Yorkshire, and then to the chalk and drift of Holderness and North Lincolnshire. His next important piece of official work was the re-survey on the six-inch scale of the northern or tertiary area of the Isle of Wight. In 1901 he took charge of the re-survey of Cornwall and Devon which was then in progress in the St. Austell and Bodmin area, and new ground was soon broken in the west by Mr. Reid and his staff. The re-survey has now been brought nearly and somewhat abruptly to a conclusion, and a new series of memoirs and maps has been sent out from the press of the Survey. Their great value is already recognized, and will be more so as time goes on, especially if an exhaustive general index, such as that prepared by Mr. Reid himself for the classic Report of De la Beche, should be added.

Mr. Reid has been already honoured by the Geological Society of London; by the award of the balance of the proceeds of the Murchison Fund (in 1886), and by the Bigsby Medal (in 1897), and in 1899 he was elected a Fellow of the Royal Society, thus receiving that scientific blue ribbon which all scientific men covet, but which only a small proportion can ever attain.

It is for his great work in connection with the re-survey of Cornwall that we desire to honour our distinguished visitor, and

this the Council has done by awarding him the William Bolitho Gold Medal.

Mr. Reid, in the name of the Council of this ancient Society, I have great pleasure in presenting you with this Medal, which has always been given to a worker in the cause of Cornish Geology.

REPORT OF THE COUNCIL

to the Annual General Meeting, October 31st, 1911.

THE past year has been comparatively uneventful in the special subjects which constitute the objects of the existence of this Society. Although the mining industry of the county continues to maintain its position, yet in spite of the high price of tin there has been but little of new enterprise or discovery.

The geological survey of the county is, we understand, nearly complete. The work which has already been completed is most valuable, and the whole when finished will undoubtedly be of the greatest importance and service.

The thirteenth volume of the Society's *Transactions* having already reached page 478, will in the ordinary course be completed in two years' time, when the Society will have been a hundred years in existence. The fourteenth volume, consisting of the "Observations on the West of England Mining Region," by Mr. J. H. Collins, F.G.S., will, following former precedents, be an extra volume. Of this, six hundred pages, with eight of the plates, have been already corrected for the press, and it is confidently expected that it will be ready for issue before the end of the present year. Five new members have been elected during the year, but the Council regret to record the deaths of Mr. J. R. Daniell, at one time a member of the Council; the Rev. P. Hedgeland, a former vice-president; and Mr. A. Somervail, an honorary member. Mr. Somervail, as a resident at Torquay, naturally worked more in Devonshire, but he was also the writer of five valuable papers in the *Transactions* of this Society. He was elected an honorary member in 1897.

The Council have received a valuable set of plans and observations on the Great North Lode at East Pool Mine from Captain J. Jennings, and they recommend his election as an associate of the Society.

The William Bolitho Medal for 1911 is awarded to Mr. Clement Reid, F.R.S., in recognition of his service to the study and knowledge of the geology of the county in his position as head of the Geological Survey. The Council are confident that the award will give universal satisfaction.

LIBRARIAN'S REPORT.

1911.

THE Librarian acknowledges, with thanks, the receipt of publications from the following:—

American Philosophical Society.
—— Academy of Arts and Sciences.
—— Geographical Society.
—— Institute of Mining Engineers.
Batavia. Jaarbock.
Belgium. Soc. Roy. Zoologique.
——. Soc. Géologique.
Bristol Naturalist's Society.
British Association.
Canada. Geological Survey.
——. Department of Mines.
——. Royal Society.
Canadian Institute.
Cape of Good Hope. Geological Survey.
Cincinnati. Society of Natural History.
Colorado Scientific Society.
Cornwall Royal Polytechnic Society.
——. Royal Institution.
Denmark. Dansk Geologisk Forening.
Dorpat. Naturforscher Gesellschaft bei der Universitat Jurjew.
Dublin Royal Society.
Edinburgh Royal Society.
—— Geological Society.
Elisha Mitchell Scientific Society.

Geological Society.
Geologists' Association.
India. Geological Survey.
Indiana. Academy of Science.
Iowa. Geological Survey.
Leicester Literary and Philosophical Society.
Liverpool Geological Society.
—— —— Association.
London and West Country Chamber of Mines.
Manchester Geographical Society.
Maryland Geological Survey.
Mexico. Instituto Geológico.
——. Sociedad Geologica.
Michigan. Academy of Sciences.
Milwaukee Public Museum.
Missouri. Bureau of Geology.
Monte Video. Museo Nacional.
New York Academy of Sciences.
New South Wales. Geological Survey.
——. Royal Society.
New Zealand. Department of Mines.
Normandy. Société Géologique.
North of England Institute of Mechanical and Mining Engineers.
Nova Scotia. Institute of Science.
Oklahoma University.
Peru. Cuerpo des Ingeniores de Minas.
Philadelphia. Academy of Natural Sciences.
Plymouth Institution.
Queensland Government.
Royal Society of Arts.
Royal Society.
Romaniei Institutului Geologic.
Saxony. Berg und Huttenwesen.
Smithsonian Institution.
Tuscany. Societa di Scienzi Naturali.
United States. Geological Survey.
Upsala. Geological Institute.

Uralian Society of Natural Sciences.
Vienna. K. K. Geologischen Reichsanstalt.
——. K. K. Naturhistorichsen Hofmuseums.
Victoria. Geological Survey.
Western Australia. Geological Survey.
——. Department of Mines.
Wisconsin Academy.
Yorkshire Geological Society.

[*From the Authors.*]

The Lignite of Bovey Tracey. C. Reid and E. M. Reid.
Scandium. Prof. Eberhard.

[*Purchased.*]

Palæontographical Society. Vol. LVIII.
London, Edinburgh, and Dublin Philosophical Magazine.

CURATOR'S REPORT.

ADDITIONS TO MUSEUM.

1911.

Presented—	*Presented by*
Buckshot Leader from Reitfontein Gold Mine, Transvaal	Mr. F. H. Uren
Specimen of Pay Reef showing Gold with Pyrites and Carbon, Reitfontein Mine, Transvaal	Mr. F. H. Uren
Rand Banket showing pebbles with high gold values, Reitfontein Mine . . .	Mr. F. H. Uren

Purchased—

Quartz Specimen from S. Just.

THE WILLIAM BOLITHO MEDAL,

which is provided for by a fund bequeathed to the Society for the purpose by William Bolitho, of Ponsandane, in 1895, has been awarded to the following members :—

1896. R. Etheridge, F.R.S.
1897. Howard Fox, F.G.S.
1898. J. H. Collins, F.G.S.
1899. F. W. Millett, F.R.M.S.
1900. Sir C. Le Neve Foster, F.R.S., etc.
1901. Thomas Clark.
1902. Dr. Richard Pearce, F.G.S.
1903. W. A. E. Ussher, F.G.S.
1904. J. D. Enys, F.G.S.
1905. Lady Warington Smyth.
1906. A. K. Barnett, F.G.S.
1907. U. Green, F.G.S.
1908. T. R. Polwhele, F.G.S.
1909. Rev. D. G. Whitley.
1910. Dr. G. J. Hinde, F.R.S., etc.
1911. C. Reid, F.R.S., etc.

W. BOLITHO MEDAL ACCOUNT.

Dr.	£	s.	d.
May 19th, 1911—			
To Gerrard and Co. for 1910 Gold Medal . .	12	10	0
October 31st, 1911—			
,, Balance	30	3	1
	£42	13	1

Cr.	£	s.	d.
November 8th, 1910—			
By Balance	24	17	4
February 15th, 1911—			
,, Dividend on £540 Great Western and Great Central Stock	8	17	9
August 15th, 1911—			
,, Ditto, ditto	8	18	0
	£42	13	1
October 31st, 1911—			
By Balance	30	3	1

STATEMENT OF RECEIPTS AND EXPENDITURE FOR THE YEAR 1910–11.

Dr. *The Treasurer in Account with the Royal Geological Society of Cornwall.* **Cr.**

Receipts.

October 31st, 1911—	£	s.	d.	£	s.	d.
To Balance from 1910				13	7	5
,, Ordinary Subscriptions and Arrears	40	19	0			
,, Subscription per His Royal Highness the Prince of Wales . . .	20	0	0			
,, One Year's Dividend on £1800 Midland Railway 2½% Debenture Stock . . . £45 0 0						
Tax at ½ . . £2 12 6						
	42	7	6			
,, Sales of *Transactions* . . .	1	18	0			
,, W. Colenso a/c Printing Photos .	8	9	0			
				113	13	6
				£127	0	11
October 31st, 1911—						
To Balance in Treasurer's hands				£19	19	5

Expenditure.

October 31st, 1911—	£	s.	d.	£	s.	d.
By Rates and Taxes	0	8	0			
,, Curator's Salary	42	7	6			
,, *Transactions*, Periodicals, Printing, and Stationery	18	8	5			
,, Fire Insurance Premium . .	3	15	0			
,, Coals and Gas	9	5	9			
,, Repairs to Buildings . . .	22	11	0			
,, Postages, Carriage, and Petty Disbursements	5	15	10			
,, Photos for Magazine . . .	3	0	0			
,, Specimen of Quartz Crystals . .	1	10	0			
				107	1	6
,, Balance in hand				19	19	5
				£127	0	11

October 31st, 1911.

T. R. BOLITHO, *per pro Hon. Treasurer.*

LIST OF PAPERS

READ TO AND PUBLISHED BY THE SOCIETY.

1911.

President's Address. J. H. Collins, Esq., F.G.S.

The Earliest Traces in Ancient History of the Tin Trade of Western Europe. Rev. D. Gath Whitley.

Recent Coast Erosion at Porthscatho. F. J. Stephens, F.G.S.

Notes on the Heaves of the Great Lode of East Pool and Agar. J. Jennings, A.I.M.M., etc.

THE EARLIEST TRACES IN ANCIENT HISTORY OF THE TIN TRADE OF WESTERN EUROPE.

By Rev. D. Gath Whitley.

In the early days of the Royal Geological Society of Cornwall the ancient Tin Trade of the West of England was a subject which constantly engaged the attention of the members. Sir Charles Lemon, Dr. Barham, and Mr. Hawkins all discussed the subject, and when I compare the hasty and impatient way in which the question is often now treated with the elaborate comparisons, logical reasoning, and laborious investigations which characterize the papers of the Founders of this Society, I am led to exclaim, in the language of Holy Writ, "There were giants in the Earth in those days." These honoured members of our Society particularly excelled in the patient and exact manner in which they unfolded the testimony of ancient writers; they gave elaborate and exact references to all their remarks; they never declared statements to be "mythical" merely because these statements happened to place difficulties in the way of their opinions; and they never said that ancient

authorities were untrustworthy, merely because these authorities contradicted their own cherished theories. May we follow the example of these Founders of Cornish geology, for it is by such patient, laborious, and long-continued researches and comparisons that we ultimately reach permanent success.

I do not intend in the following paper to describe the ancient Tin Trade of Cornwall in general. I shall merely discuss the two *oldest* authorities on this subject, and examine what light they throw on the vexed question of the situation of the Tin Regions in Western Europe at the dawn of the historical era.

The first of these authorities that I shall quote is Herodotus. Now, the testimony of Herodotus has not been treated fairly in this discussion. It has been said that he knows nothing of the situation of the Tin Regions, and that therefore no reference whatever should be made to him. This is an entirely incorrect way of judging the case. It is true that Herodotus does not determine the *exact* position of the Tin Regions, but *indirectly* he shows the direction in which they are to be found, whilst the reason for the erroneous judgment passed upon his statements is partly because the context of the passage in which he refers to the Tin Regions is not quoted and partly because no attempt is made to explain the real significance of what he *does* say. The words of Herodotus, which it is necessary to examine minutely, are as follows :—

"Ethiopia, which is the extremity of the habitable world, is contiguous to Arabia on the south-west. This produces gold in great quantities, elephants with their prodigious teeth, trees and shrubs of every kind, as well as ebony; its inhabitants are also remarkable for their size, their beauty, and their length of life. The above are the two extremes of Asia and Africa. Of that part of Europe to the west I am not able to speak with decision. I by no means believe that the Barbarians give the name of Eridanus to a river which empties itself into the Northern Sea, whence it is said our amber comes. Neither am I better acquainted with the islands called Cassiterides, from which we are said to have our tin. The name Eridanus is certainly not barbarous; it is of Greek derivation, and, as I should conceive, introduced by one of our poets. I have endeavoured, but without success, to meet with someone who from ocular observation might describe to me the sea which lies in that part of Europe. It is nevertheless certain, that both our tin and our amber are brought from those extreme regions." *

Now, there are three preliminary conclusions to be drawn from this paragraph before the situation of the Tin Islands is discussed.

First. Herodotus distinctly declares that *all* the tin used in Eastern Europe and Western Asia came from the Cassiterides. From the way he

* *Thalia*, CXIV, CXV. I quote from Beloe's *Herodotus*, Vol. II, pp. 134–6.

speaks it is evident that this was well known. Theorists have speculated upon tin being brought in ancient times from Circassia, or the Hindu Kush, or the Altai Mountains. Herodotus knows only of *one* great source of the tin used in his day, and this was the Cassiterides. Any other regions, if they really *did* exist, were too insignificant to be mentioned.

Secondly. The Cassiterides were *islands*—all the ancient authorities are agreed in this—so that they must have been reached by a sea voyage.

Thirdly. As the tin brought from the Cassiterides was the *sole* supply of the regions of Greece, Asia Minor, and Syria in the days of Herodotus, and had been for centuries, it is evident that the supply was *very great*, and that the amount of tin raised in the Tin Islands must have been *very considerable.* It follows that the Cassiterides must have been *large* islands containing very extensive districts full of tin. Mere islets or isolated rocks rising out of the sea will not meet the case. We are clearly dealing with a *group* of islands of which, if some were small, others must have been of considerable size.

We know that Tyre was the great mart from which the tin was distributed throughout Western Asia and Eastern Europe. From the Old Testament authorities we learn the tin was brought to Tyre from Tarshish by means of a sea voyage along the Mediterranean Sea. This Tarshish was the land containing the Phœnician colonies in the

south of Spain, of which Gaddir (or Gades) was the chief. It was to Gaddir that the tin from the Cassiterides was brought by sea, and was from thence forwarded, also by sea, to Tyre.

But it is said that Herodotus admits that he knows nothing about the position of the Cassiterides. Let us minutely examine his statements. In the paragraph I have quoted he is describing the extreme limits of Asia, Africa, and Europe. So far as Asia is concerned, its most distant region towards the south-west is Arabia. The extreme limit of Africa to the south is Ethiopia, about which he gives many details. Next he considers the furthest western regions of Europe, and confesses that he knows but little about them. Then he speaks of the north of Europe, and the ocean in that direction. He says that there is here a great sea, and he has a vague idea of mighty rivers flowing into it, but he met no one who had visited them. In this sea lying to the north of Europe, he places the Cassiterides, or Tin Islands, although he is ignorant of their precise situation. It is certain, however, that Herodotus placed them in Northern Europe, because he mentions the amber trade in connection with the Tin Islands. This is a most important link in the chain of evidence. The amber coast, from which such large quantities of this material were carried to Greece and Italy, lay exclusively in Northern Europe. It reached from Holland to the shores of the Baltic, small quantities of amber being found on the coasts of Eastern

England and Scotland. One of the chief sources of this precious commodity was the Amber Islands, otherwise called Electrides or Glessariœ, which stretched from the mouth of the Rhine to the estuary of the Elbe, and from which the Roman fleet in Nero's time collected 13,000 lbs. of amber in a single visit. In Eastern Prussia, near the shores of the Baltic also, the amber was obtained in great quantities, as it is even now, from pits. In the northern regions of Europe Herodotus mentions a river called Eridanus, on the banks of which amber is found, which is probably the Vistula, although Larcher identified it with the Rhodane, a tributary of that river. Hesiod also mentions the same river, and says that amber trees are found on its banks. From the shores of the Baltic and the North Sea the amber was carried to the south by two routes. The western one ran from the mouth of the Elbe through Bohemia and Lombardy to the city of Hatria, at the head of the Adriatic Sea. The eastern route passed from the mouth of the Vistula through Upper Austria to Trieste, also on the Adriatic.* To show that tin and amber both came from the northern regions of Europe, we are further told that two statues, one of tin and the other of amber, were erected near Trieste, which was the southern end of one of these great trade routes.† Herodotus sums up his account of tin and amber in these striking words:

* *Early Man in Britain*, by W. Boyd Dawkins, pp. 466–8.
† *Origins of English History*, p. 13.

"I have endeavoured, but without success, to meet with someone who from ocular observation might describe to me the sea which lies in the northern part of Europe. It is nevertheless certain that both our tin and our amber are brought from those extreme (northern) regions."

This settles the question as far as Herodotus is concerned. All the information he had gained from the Phœnician traders placed the Cassiterides in the north of Europe, and in that great northern sea on the shores of which amber was found. According to Herodotus, therefore, the Tin Islands could not have been situated off the north-western coasts of Spain.

But, further, Herodotus mentions that in the extreme west of Europe, beyond the Pillars of Hercules, there dwelt a people called Kynesii or Kynetes.* These lived beyond the Celtœ in the furthest point of Europe towards the setting sun. Herodotus does not fix their precise locality, but Festus Avienues and other writers place them in the extreme west of the Spanish peninsula. Professor Rhys considers them to have been a pre-Celtic race, and descendants of the primitive Neolithic inhabitants of Western Europe.† Here, then, were the people of Western Spain, but as Herodotus does not mention the Cassiterides in connection with the Kynesii, it is perfectly clear that this is another proof that in the days of Herodotus

* *Herodotus*, Lib. II, cap. XXXIII, and Lib. IV, cap. XLIX.
† *Celtic Britain*, pp. 261, 262.

the Tin Islands were not considered to lie off the north-western shores of Spain, but were believed to be in the sea of Northern Europe.

My second authority that I shall discuss is Himilco the Carthagian.

About 500 B.C. Carthage sent out two great exploring expeditions. One, under the command of Hanno, was to sail southwards along the western shores of Africa. The other, in charge of Himilco, was to explore the ocean which lay to the north of Spain and Portugal. Both expeditions were equally important, and were equally honoured on their return by having golden tablets containing accounts of their voyages placed in the temple of Moloch at Carthage. Hanno's account has been preserved, and is considered to be one of the most valuable of geographical statements in Ancient History, as his voyage coasted the western shores of Africa as far south as the River Gaboon.*

Unfortunately Himilco's narrative is lost, and we have to depend on brief notices of his voyage which are preserved by Festus Avienues, who wrote about A.D. 350, and by Pliny.

From these we gather that Himilco's ships leaving Gaddir (or Cadiz) first rounded the Sacred Promontory or Cape St. Vincent. Then, sailing northwards, the vessels reached the great Œstrymnian Promontory, which sloped towards the south.

* The best accounts I have seen of these two expeditions are in Lenormant's *Manual of Ancient History of the East*, Vol. II, pp. 263–7, and *Early Man in Britain*, by Professor W. Boyd Dawkins, pp. 457–9.

Much difference of opinion exists as to the identity of this headland. Mr. Elton thinks it was Cape St. Vincent,* and Mr. Kenrick Cape Finisterre; † while Professor Heeren and Dr. William Smith consider it to have been the Lizard. It seems to me that Cape Finisterre is intended. Himilco next crossed the great Œstrymnian Bay, which is probably the Bay of Biscay, which at that time abounded in sea-monsters. Continuing to coast the shore, Himilco's ships then reached the holy isle of Sena, in which there was a temple served by twelve priestesses who were supposed to have power over the winds and waves, and were therefore much sought after by mariners in order that they might have a propitious voyage. In a paper read before the Royal Institution of Cornwall, I have pointed out that the priestesses on this island formed, like those on other islands in Northern Europe, a college, and that they were devoted to the worship of the great Serpent Divinity of the Ocean. The precise determination of the island of Sena is a point of great importance in fixing the course of Himilco's voyage. There is little doubt that it is now represented by the island of Sein which lies off the western extremity of Brittany, not very far from Brest. Pomponius Mela, a Spaniard, who wrote in the first century A.D., says that the island of Sena lay in the British Seas, a portion of the ocean which stretched from the mouth of the Loire to the British Isles. It will be seen from this that

* *Origins of English History*, p. 20. † *Phœnicia*, p. 217.

we have traced Himilco's ships to the western entrance of the English Channel.

Now comes the vital point. Leaving Sena, Himilco's fleet reached the islands called the Œstrymnian Islands, which were large and populous, and rich in tin and lead. Where were these islands, and how are we to identify them? Let us ask ourselves, what regions which produce tin in large quantities lie in the sea to the north of Brittany? The answer cannot be doubtful; the tin-producing districts of Cornwall and the Scilly Isles must be meant. But this is rendered certain by what follows. Avienus tells us that after sailing two days from these Tin Islands the vessels of Himilco reached the green Sacred Island inhabited by the Hibernians, which, of course, is Ireland. Now let anyone take a map and see what tin-producing regions exist which are situated half-way between Brittany on the south and Ireland on the north. Again the reply is certain, only Western Cornwall and the Scilly Isles can be found. In a short time from Ireland Himlico's fleet reached the coasts of island of Albion, which is, of course, Britain. The derivation of the name is unknown, and Professor Rhys considers that it originated among the pre-Celtic inhabitants of Britain, as it is the earliest name by which our island is known.* We see, therefore, that Himilco's vessels were now voyaging along the shores of Western Britain and Ireland.

* *Celtic Britain*, p. 203.

But let us examine particularly the account which the chronicler of Himilco's voyage gives of the Œstrymnian Islands, and see with what islands it nearest agrees. According to some authorities, the islands which were the real Cassiterides were *not* the Scilly Isles, but three groups of small islands which lie close to the shore of Gallicia at the north-western extremity of Spain, and are situated at the entrance of the bays of Vigo, Aroso, and Pontevedra.* Now, the Tin Islands of Himilco (or the Œstrymnides) "rose out of the sea," which clearly means that they were far out in the ocean with sea on all sides. This is true of the Scilly Isles, but it is *not* true of the Spanish islands before mentioned, as they lie at the mouth of bays, not far from the shore, one of them being joined to the land by a sandbank. Himilco's Tin Islands were large and populous, which could not have been the case with the islands off Vigo Bay, but the Scilly Isles and Western Cornwall must in Himilco's time have supported a large population. Himilco found the Tin Islands to be scattered over wide expanses of the ocean, and to be separated from each other by broad spaces of sea. This exactly corresponds to the distances between different portions of Western Cornwall and the Scilly Isles, but it is hard to see any resemblance to this description in the before-mentioned Spanish islands, which are grouped closely together, and lie so close to the shore that

* See *The Dolmens of Ireland*, by W. C. Borlase, Vol. III, pp. 1232–3

a voyager coasting the shore, but giving the land a sufficient offing for safety, would consider them most insignificant objects, and by no stretch of the imagination could they be said to "rise out of the sea," as was the case with Himilco's Tin Islands.

But, further, Strabo gives an account of what was known of the Tin Islands or Cassiterides in his day, and the description so precisely resembles the details given of Himilco's Tin Islands that we are compelled to conclude that both accounts describe the *same localities.* Now, Strabo gives exact distances, and locates his Tin Islands with such precision that we see at once that they lay in the seas of Northern Europe in the neighbourhood of Britain. It follows, therefore, that Himilco's Tin Islands must have been situated in the seas of Britain also.

It is also interesting to notice that Avienus, in describing the inhabitants of Himilco's Tin Islands, speaks of their navigating the sea around the islands in wicker and skin-boats: in other words, in the frequently described coracles. This would lead us to suppose that the well-known British coracles of basket-work are intended, which are even now used in some rivers in Wales and Ireland, and it would form another link in the chain of evidence which identifies Western Cornwall and the Scilly Isles with the Tin Islands of Himilco. The opponents of this identification, however, challenge this statement, and maintain that the Spanish and Portuguese

coracles were well known in ancient times, and that these may be referred to, so that the Œstrymnian Tin Islands may have been situated off the coast of Gallicia in Northern Spain.

It may be so, but all the accounts of coracles that I have read in Ancient History refer to British coracles, and they are all associated with British tin and lead. If the word "coracle" is looked up in a geographical or social encyclopædia, you are pretty sure to find references to British coracles alone. It is exactly so amongst ancient writers. No one denies that Spanish coracles may have existed, but geographers and historians of ancient days in their writings generally linked together the tin, the lead, and the coracles of Britain. Thus, when Pliny describes the tin and lead of Britain, he refers in the same place to the coracles. Timœus also speaks of the tin region of Britain, and relates that the inhabitants voyaged to the place where the tin was sold in coracles of wicker-work covered with hides. The fair conclusion is, therefore, that when Avienus mentions the tin and lead in the islands of Himilco in the northern seas, and then speaks of the coracles, he refers also to the tin, lead, and coracles of Britain.

If the Œstrymnian Islands of Himilco were *not* the Scilly Isles and Western Cornwall, we may well ask where *were* they? In despair of discovering their situation, those who refuse to accept this identification are driven to deny the truth of Himilco's voyage altogether, and to consider it as

a mere fable. This, however, cannot be done without equally denying the truth of Hanno's contemporaneous voyage. For *both* voyages were honoured as equally true by the Carthaginians, and *both* recorded on golden tablets placed in the temple of Moloch in Carthage. Hanno's voyage is admitted by all scholars to have been a *real* expedition and to have been truly recorded. It follows, then, that the voyage of Himilco must have been equally true.

To take a specimen of these difficulties. If the Tin Islands of Himilco lay off the Gallician coast in North-Western Spain, near Vigo, where is the great Œstrymnian Gulf which Himilco's ships crossed before reaching the Tin Islands? It does not exist. The whole of the Portuguese coast from Lisbon to the so-called Tin Islands is perfectly straight and unbroken, and contains no large gulf whatever. A glance at the map will show that such an identification of the Tin Islands with the scattered islets at the entrance of the bays of Vigo and Pontevedra is absolutely impossible. Western Cornwall and the Scilly Isles are the only tin-producing districts which in any sense will suit the descriptions of the islands of Himilco.

To sum up. If any reliance can be placed on Ancient History, Herodotus certainly places the Cassiterides in the sea of Northern Europe, where Britain alone answers to his description. Himilco's Tin Islands cannot be located anywhere but in the neighbourhood of the regions of North-Western

Europe, not far from Ireland and Britain. It seems to me impossible to escape the conclusion that the tin-producing regions visited by the Carthaginian navigator were Cornwall and the adjacent islands.

RECENT COAST EROSION NEAR PORTSCATHO.

By F. J. Stephens, F.G.S.

Porthcurnick beach lies about half a mile north of Portscatho village in Gerrans Bay. It is a flat, sandy beach in a cove which faces the east and south-east, and when, as recently, heavy gales from this quarter blow in, the seas in the cove are tremendous.

During the past summer the beach has been very free from pebbles, and the fine flat sandy reach has been much appreciated by visitors for bathing purposes.

On the western or land side of the cove is a large accumulation of what is probably blown sand extending inland, but exposed only along the cliff edge, pasture land extending to the edges of the cliff and beach.

A parish road which formerly crossed the edge of the beach above high-water mark has now been completely swept away within the past fifteen years, and at spring tides the sea comes in several yards beyond the line where it once ran.

The recent gales have had several curious effects

on the south-western portion of the beach, some six to ten feet of the sand cliff having been swept away and a new and nearly perpendicular section being exposed.

During the summer and for some time past, this portion of the cliff has been simply an irregular and tumbled slope of sand and earth fallen from the cliff top.

The present section shows for the moment clearly from the cliff edge to the beach.

From the southern part of the cove, where the height is some twenty-five feet above sea level, the cliff edge descends to a point nearly level with the sea, where a little stream issues from the valley beyond on to the beach. Beyond northward the cliffs rise rapidly again to a height of thirty feet, and turn sharply eastward towards Pedn Vedn Point.

Looking westward from the beach south of the stream, one observes the following section. A short narrow thickness (barely six inches) of soil forms the upper portion of the cliff. Below this a lenticular band of perfectly white sand, with many shells, not of marine origin, extends from a mere wedge at the top of the cliffs south of the cove until it reaches a thickness of fifteen feet, after which it fines away rapidly towards the north. Underlying this is now to be seen an ancient line of soil some six inches thick, which is again underlain by another lenticular band of ancient reddish sand, which possibly marks another ancient mass of blown sand.

This ancient sand also contains a few shells of similar appearance to those in the white sand above. It contains, moreover, what is not to be observed in the newer sand above—many angular fragments of various rocks, few of large size, usually an inch or two in diameter, some few of which are flat and rounded. One curious point is that many of these small pebbles are on edge, embedded in the ancient sand.

This reddish or lower sand dips beneath the beach near the stream, and reappears below the present soil to the north, merging gradually into the "Head," which continues around the coast in this district in a more or less even band, some six feet thick, above the upturned edges of the "Portscatho" slates.

This "Head," here containing an unusual quantity of large broken fragments of slate and quartz, is seen in the south corner of the cove and beach, bending upward from beneath the ancient sand mass to the top of the cliffs, and extending south towards Portscatho.

This portion of the "Head" has been greatly scooped out by the recent gales, and the large angular fragments of the contained rocks have been swept by the force of the sea to a point many yards distant, where they lie piled up as a rocky bank near high-water mark across the beach. Another curious feature of these alterations is that large fragments of the low rock reefs to the south of the cove have been bodily broken off, showing in one

place a previously unobserved thin layer of conglomerate, or possibly ancient volcanic breccia, which cannot be traced far in any direction.

All along the lower portion of the beach near the low-water mark the once sandy surface is now covered with innumerable fragments of rock, mostly swept from the disintegrated reddish sand alluded to earlier. These fragments, although mostly still angular, are rapidly being rounded by the action of the waves.

Most of these fragments are similar to the local rocks *in situ*, but nevertheless some appear to have been torn originally from places far distant. Amongst others I have observed fragments of tinstone, pieces of radiolarian chert (also observed as pebbles in fields high up the valley above), fragments of serpentines and other Lizard rocks, and pebbles of hard jaspery rock.

It is difficult and perhaps unprofitable to speculate on the forces which have deposited the interesting deposits of sand in the situation where they are now to be seen so distinctly. It is customary to speak of such deposits as "blown" sand, but it is difficult to explain the apparently sudden overwhelming of what was once pasture as evidenced by the ancient soil surface exposed.

We may assume the close neighbourhood of the sea even then, and it would apparently require a combination of extraordinary and continuous high tides, with perhaps fierce cyclonic winds, to overwhelm a tract of land so completely.

We have, of course, historical evidence that in the eleventh and thirteenth centuries there were great inundations and destruction of lands all over the South of England, and perhaps the ancient soil section now exposed was then overwhelmed, but it has always appeared to me that to attribute such deposits to entirely cataclysmal causes is not altogether satisfactory theorizing.

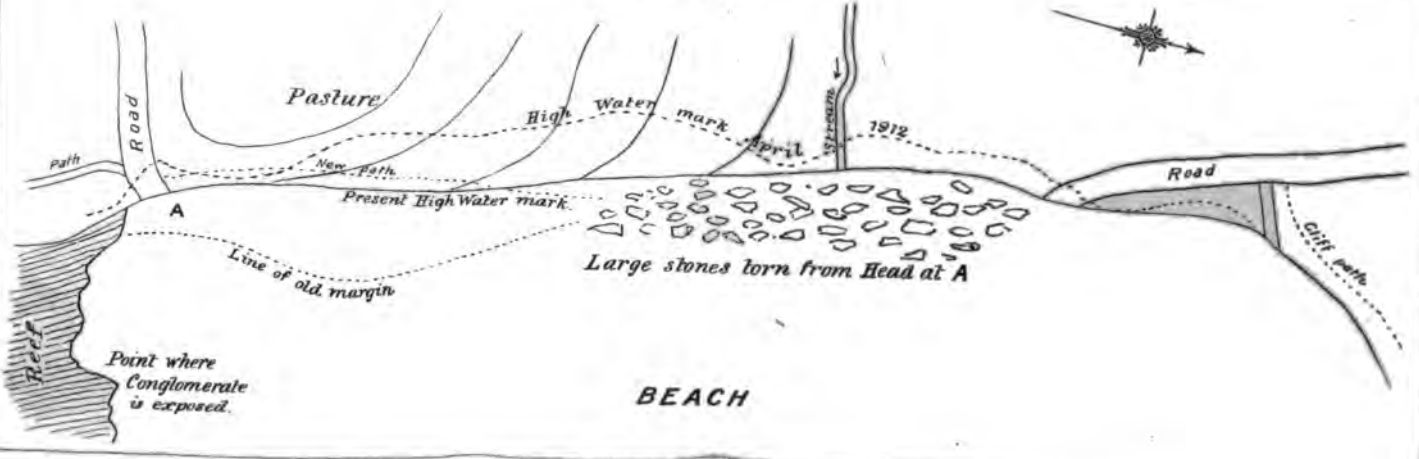
As, however, our province is to record facts, and as undoubtedly the present section will shortly be obscured by the falling of fresh sand and soil from above, I have thought it as well to place these observations on record.

Postscript.—Since the above notes were written in November a series of devastating south-east gales has swept this shore. In one of these the German ship *Gustav* went ashore in this very cove.

Fully ten feet further of the exposed sand has been swept away, the footpath to the beach has gone entirely, and some part of the ancient soil-line has now disappeared.

PORTHCURNICK BEACH SECTION
LOOKING WEST INLAND.
Road
Soil
White Blown Sand
Ancient Soil Line
Reddish Sand with Scattered Pebbles
Portscatho Slates
Head
Reef
Stream
Soil
Red Sand and Scattered Pebbles
Head
Portscatho Slates.
Beach Line at High Water mark about 50 yards.

PLAN.


Road
Path
Pasture
High Water mark April 1912
Stream
New Path
Present High Water mark
A
Line of old margin
Large stones torn from Head at A
Road
Cliff path
Reef
Point where Conglomerate is exposed.
BEACH

NOTES ON THE HEAVES OF THE GREAT LODE OF EAST POOL AND AGAR,

With Two Plates showing Plans and Sections.

By Joseph Jennings, A.I.M.M., A.R.G.S., of Cornwall,
Manager East Pool and Agar Mines.

I HAVE purposely given this title to my remarks because it may one day open the subject of "Primary and Secondary Lodes and Heaves of Cornwall." I am afraid that this subject has not had the attention it should have had in days gone by, and I am not alone in my opinion when I say that if this important and interesting subject had been better studied years ago, many of our Cornish mines that are now lying abandoned would never have ceased to produce.

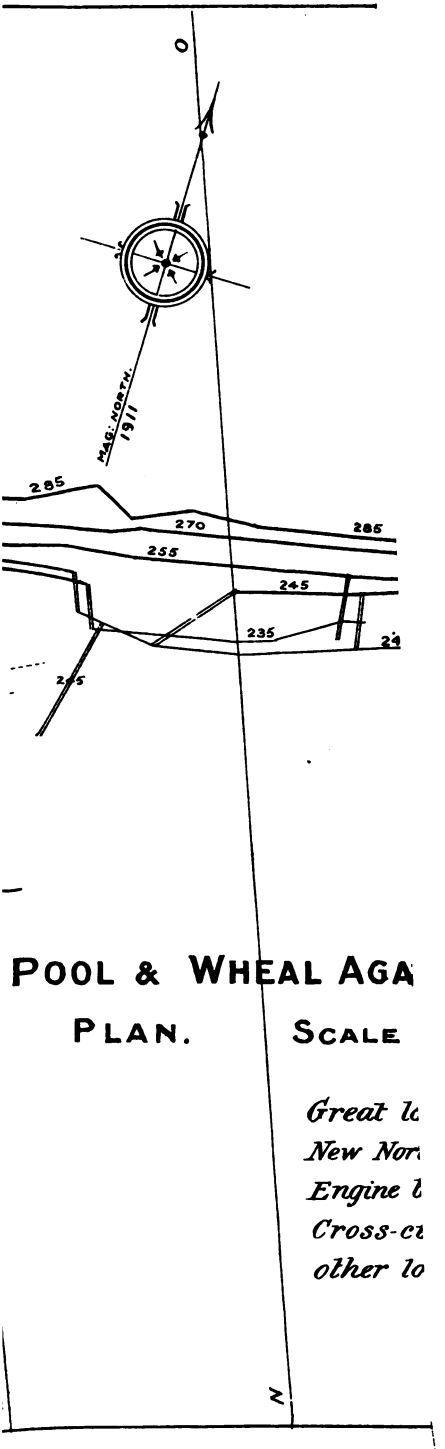
Regarding the occurrence of the lodes in the particular mines with which I happen to be connected, I may say that it forms a particularly interesting subject, but there are several difficulties in connection with what may be called our Secondary Lodes, many of which have a southern underlay; therefore I propose to deal principally with the Primary Lode of the district, viz. the Great North Lode.

The Great North Lode, or what we now call "The Great Lode," was discovered in the year 1860. The then named North Shaft of East Pool Mine having been sunk perpendicularly to the 130 fm. level under the adit, or 900 ft. below the surface intersected the "Engine Lode," called at that time the North Lode to distinguish it from the South Lode, which was being greatly wrought from South Shaft.

There appears to have been considerable diversity of opinion as to the advisability of diverting the shaft to the dip or underlay of the North Lode, or to keep sinking vertically. Had the advocates for the diversion succeeded in their cause the Great North Lode would not have been discovered, at any rate not for some time.

The shaft sinking, fortunately, was continued vertically, and at about 5 or 6 fathoms below the 130 fm. level a lode was struck containing tin, arsenic, wolfram, copper, and many other metals which go to make up a complex ore. The lode was of great width and easily worked, so that they rightly called it the *Great* North Lode.

From that time increased prosperity accompanied the mine, and upwards of £500,000 have been paid in dividends to the fortunate shareholders. Thus it happened that the top or middle of the heave of the so-called South Lode was discovered, backing up against the North or Engine Lode. During the course of years the lode was greatly wrought (as indicated above and on the longitudinal section) to



POOL & WHEAL AGA

PLAN. SCALE

Great la
New Nor
Engine l
Cross-cu
other lo

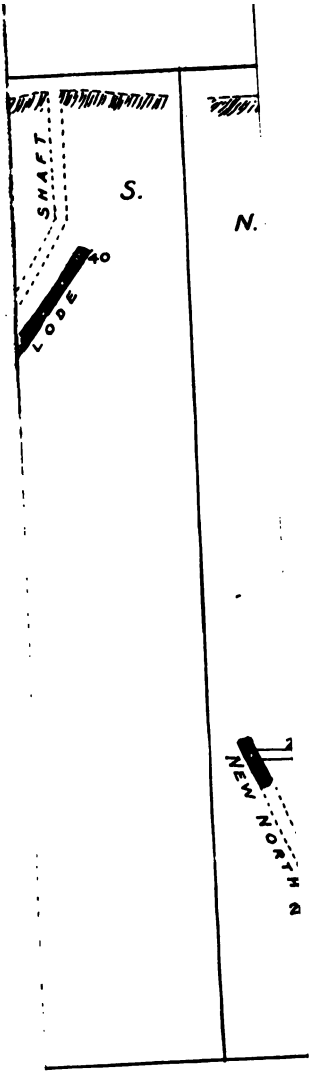
about the 212 fm. level under the adit, or about 1400 ft. below the surface, where another lode cut it off, and it is yet to be found by cross-cutting north. This will be done as soon as certain pumping arrangements to deal with probable increase of water from any developments to the north, have been completed.

I now come to the cross sections. They are ten in number, and represent views of the lodes along the lines marked out on the Plan at a—b, c—d, etc., 32 to 64 fathoms apart; there may be more, but the general information gained would be the same.

I have coloured the Great Lode crimson, and the South Lode is shown in the same colour, because it has also produced large quantities of similar complex ore, and is of the same underlay (north); moreover, from these sections it is apparent that the South Lode and the Great Lode are one and the same, having been repeatedly heaved or thrown downwards in the process of movement of the crust of the earth along the lines of least resistance, which happen to be in this case the Secondary Lodes, herein named the Engine Lode, Middle Lode, and the New North Lode. The course of the downward movement may be distinctly seen at the 130 and many other places, in foot and hanging walls. The lodes are not quite parallel, they converge slightly in their course to the east, therefore the longitudinal section shows the back or saddle of the heave dipping east.

There are other lodes in the district, viz. the

Caunter, Red, and New South Lodes. Possibly they may represent a *third* period. For instance, the Caunter Lode cuts off the Engine Lode at the 228 level, and the Red Lode heaves the New North Lode down 16 ft. at the 280 and the 310 levels, where development disclosed profitable ore bodies along the line of both contacts. These deposits contain no wolfram nor arsenic, but the "black tin" is of a particularly pure nature, carrying over 68 per cent of metal.


SHAFT
S.
N.
40
LODE
NEW NORTH 2

10) on line P.Q.

S.
ENGINE LODE
245
255
270
GREAT LODE

R89
G347

Vol. XIII. Part IX.

TRANSACTIONS

OF THE

Royal Geological Society

OF

CORNWALL,

INSTITUTED FEBRUARY 11th, 1814.

The Ninety-ninth Annual Report of the Council,

WITH THE

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THE NINETY-NINTH

ANNUAL REPORT

ETC.

PENZANCE.

1913.

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THE
ANNIVERSARY ADDRESS OF THE PRESIDENT,

J. H. COLLINS, Esq., F.G.S.

To the General Meeting, November 12th, 1912.

Ladies and Gentlemen,—I feel that I cannot enter on the duties of this chair to-day without referring to the heavy loss we have sustained by the death of our late President, John Davies Enys. As I stood by his grave yesterday I could not but remember his unfailing geniality and broad-mindedness and his energy, perseverance, and generosity in promoting every branch of science, art, and literature which had reference to our West of England or to the Dominion of New Zealand. As President, in some cases more than once, of all our Cornish scientific societies, as also of the Devonshire Association, his services were always available and always valued by those who had the pleasure of serving with him as colleagues. I know not where we are to look for his successor.

I do not propose on this occasion to trouble you with a lengthy Presidential Address, but I feel that a few remarks should be made from this chair upon the renewed energy which has become evident in connection with our West-Country mining during the past few years, and especially during the past year. This has no doubt resulted in large measure from the greatly enhanced price of tin, due to the evident fact that, in spite of some recent and important discoveries in South Africa and Nigeria, the world's production hardly keeps pace with the continually growing demand for this metal. Neither Cornwall, nor Australia, nor Bolivia, nor even the East Indies and Straits Settlements seem able to increase their production in proportion to the increasing consumption of the world.

The new Cornish projects are not, as formerly, almost entirely confined to schemes for reopening deep and extensive abandoned mines, there being several whose objective is the testing of shallow and hitherto almost unworked areas of what is called "virgin ground," adjacent to mines which were formerly very productive. There are also large plans for working ancient or modern tin-bearing alluvial accumulations in several parts of our county. This recrudescence of alluvial mining in the West calls for a few words of special comment. Our late President, Mr. Wm. Jory Henwood, in his address as President of the Royal Institution of Cornwall nearly forty years ago, gave an account of the numerous tin stream-works which had come under his notice, some of which had been worked intermittently for centuries. All these were concerned with natural detritals, but the industry was then practically at an end and the natural deposits were thought to be exhausted, or very nearly so, and at any rate no longer payable. In the meantime the very name of "tin-streaming" had been applied to processes for recovery of tin from the refuse of the mines which passed down the Red River and other streams in the mining districts of the West. These operations have grown to very considerable dimensions, so that from 1881 to 1909 no less than 31,548 tons of black tin, which realized £1,310,149, were recovered from the refuse of the mines. Encouraged by the brilliant success which has attended the treatment of the old refuse-heaps of the Carn Brea and Tincroft Mines by Mr. Richards and his associates, several companies have been recently formed which will undertake the treatment of other waste-heaps, and also of what may be called artificial alluvials, on a very large scale, such as exist in the St. Erth Valley, at Gwythian, in the Carnon Valley, and elsewhere.

For the renewal of work on the natural alluvials, I believe that I may claim much of the credit, as I was the first to obtain a grant of a sufficiently large area of tin ground on the Goss and Tregoss Moors as far back as the year 1906, and to commence operations thereon, with the aid of steam machinery, as set forth in the Report of the Royal Cornwall Polytechnic Society for 1909, and illustrated by specimens of the products obtained in the

FIG. 1. ACTINOCERAS DEVONICANS (about ⅓ actual size), FROM ROPE HAVEN, ST. AUSTELL BAY.

Polytechnic Exhibition at Camborne in 1908. The small operations undertaken by myself and associates led to a transfer of the property to a syndicate of gentlemen having Australian experience in tin-dredging. Since then work has been carried out on an extensive scale on Goss Moor, as also on Redmoor, Breney Moor, and other places. Full statistics of the results so far attained are not as yet available, but Goss Moor alone has yielded no less than seventy tons of black tin of the very highest quality. In these enlarged dredging operations both suction dredges and bucket dredges have been employed. It is too soon as yet to pronounce finally in favour of either, but the probability is that suction dredges will be found best for treating gravels, especially where the bottom or "shelf" is very irregular, while bucket dredges will be found most suitable for sands which will flow to a dredge-pit or "pocket."

The new mining projects have hitherto been practically limited to tin and a little wolfram, although other metal prices have been similarly enhanced. It may be that there are not sufficient indications of the existence of payable copper deposits to induce speculators to undertake a search for copper ores in the West Country, but I see no reason why some of our lead, zinc, and iron deposits should not be wrought on modern lines.

But, after all, high prices and keen demand do not suffice to set up a profitable industry, else the uranium mines, with their associated radium, should be highly flourishing from the miner's point of view. The discovery of radium, not only in the uranium ores which exist in such considerable quantities in several of our mines, but also in natural waters and in many rocks, has been of immense importance from a scientific point of view. Its isolation has also, no doubt, provided remunerative work for a few chemists. It must, however, be admitted that so far no miner's fortune has been made by radium; in this, as in some other directions, almost unlimited patience seems to be called for and the genuine mining speculator must be content to wait; and this should not surprise us if we remember that this rare product only exists to the extent of one or two ten-millionth parts in an originally costly ore such as pitch-blende.

On the whole, I think the mining projects lately initiated promise much better than did most of those which were started five or six years ago, only a few of which can be said, so far, to have met with any notable measure of success. I believe there is a better appreciation on the part of those in control of the new projects than there was aforetime of the real requirements of the mining industry in this part of the world, and more disposition to make use of and profit by the experience of men who have been familiar with Cornish conditions during long periods in the past.

The continued extension and prosperity of our china-clay and china-stone industries is a matter for congratulation. The full statistics for 1911 are not yet available, but the 790,335 tons valued at £514,330, produced in 1909, were increased in 1910 to 841,868 tons valued at £563,966.

To-day we have presented to us an important paper by a china-clay expert and merchant on the characters and modes of occurrence of china-stone or Petuntzyte. To this paper the Council have awarded a "Bolitho Prize" of £10.

It is now my duty, as it is my pleasure, to present the Bolitho Medal for 1912 to Mr. George Barrow, who, in accordance with the terms of the trust, has, in the opinion of the Council of this Society, done much good work in elucidating the geology of Cornwall. Mr. Barrow is a distinguished officer of the Geological Survey, and I have here particulars covering his work in the South-West of England during the past six years, his studies extending from the Scilly Isles to the East of Dartmoor. In these he has dealt with many geological, petrological, and chemical problems in a very illuminating way. I will not trouble you with the details now, but so far as they relate to the West of England they are fully set forth in the recently published *Memoirs of the Geological Society*.

Mr. Barrow, I now ask you to receive this Medal as a mark of the keen appreciation which this Society has of your scientific work in the West of England.

FIG. 4. x2.

FIG. 2. *Nearly Full Size.*

FIG. 3. x2.

FIG. 5. x6.

ACTINOCERAS DEVONICANS, FROM ROPE HAVEN, ST. AUSTELL BAY.

Blackford, Publisher, Truro.

REPORT OF THE COUNCIL

to the Annual General Meeting, November 12th, 1912.

In reviewing the events of the past year the Council must give first place to the record of the great loss the Society has sustained by the death of Mr. J. D. Enys, of Enys. A man of many interests and most varied information, his kindly, sympathetic character won for him universal popularity in the many prominent positions which his clear intellect and great public spirit deservedly attained throughout the county.

From the time of his return from New Zealand he never failed in his support of this Society. A member in 1893, elected one of the Council in 1894, he was also President in 1897, 1898, 1899, 1900, and was awarded the William Bolitho Medal in 1904. His death is probably an even greater loss to this and the other scientific societies of Cornwall than to the public bodies which he served so usefully.

The Council have during the year awarded a prize of £10 to Mr. J. Jennings for his paper on the "Heaves of the Great Lode of East Pool and Agar." They hope that this announcement will stimulate original research, and take this opportunity of mentioning that prizes are offered annually for new observations or discoveries in Geological or Mineralogical Science.

The valuable and important work by Mr. J. H. Collins ("Observations on the West of England Mining Region"), which forms Vol. XIV of the Society's *Transactions* referred to in last year's Report, has been published during the year. By special arrangement with the author the Society is able to offer to each of the members one copy at 15*s*.

The high price of tin is naturally attracting attention to Cornwall and to the records of the mineral wealth and history of

the county. The Council are pleased to report that in the course of the enquiries and the study of the subject now being made the publications of this Society, notably Vol. V and the new Vol. XIV, are proving most useful.

The Council have decided to award the William Bolitho Medal for 1912 to Mr. George Barrow, F.G.S., of the Geological Survey, in recognition of his service to the county in connection with that most useful work for so many years.

The maps of the new one-inch survey, except that of the Lizard, which is expected shortly, are now in the possession of the Society and available for the use of the members.

During the next twelve months the Council will begin to make arrangements for a fitting celebration of the Centenary of the Society in 1914, for which occasion the Society relies on the cordial support of the members and all others interested in the public and intellectual life of Cornwall.

LIBRARIAN'S REPORT.

1912.

THE Librarian acknowledges, with thanks, the receipt of publications from the following:—

American Philosophical Society.
—— Academy of Arts and Sciences.
—— Geographical Society.
—— Institute of Mining Engineers.
Batavia. Jaarbock.
Belgium. Soc. Roy. Zoologique.
——. Soc. Géologique.
Birmingham and Midland Institute Scientific Society.
Bristol Naturalists' Society.
British Association.
Canada. Geological Survey.
——. Department of Mines.
——. Royal Society.
Canadian Institute.
Cape of Good Hope. Geological Survey.
Colorado Scientific Society.
Connecticut Academy of Arts and Sciences.
Cornwall Royal Polytechnic Society.
Denmark. Dansk Geologisk Forening.
Dorpat. Naturforscher Gesellschaft bei der Universitat Jurjew.
Dublin Royal Society.
Edinburgh Royal Society.
Elisha Mitchell Scientific Society.

Geological Survey.
Geological Society.
Geologists' Association.
Glasgow Geological Society.
India. Geological Survey.
Indiana. Academy of Science.
Kolozsvar Museumi Fuzetek.
Leeds Philosophical and Literary Society.
Leicester Literary and Philosophical Society.
Liverpool Geological Society.
—— Literary and Philosophical Society.
London and West Country Chamber of Mines.
Manchester Geographical Society.
Maryland Geological Survey.
Mexico. Instituto Geológico.
——. Sociedad Geologica.
Michigan. Academy of Sciences.
Milwaukee Public Museum.
New York Academy of Sciences.
New South Wales. Geological Survey.
——. Royal Society.
New Zealand. Department of Mines.
Normandy. Société Géologique.
North of England Institute of Mechanical and Mining Engineers.
Nova Scotia. Institute of Science.
Peru. Cuerpo des Ingeniores de Minas.
Philadelphia. Academy of Natural Sciences.
Plymouth Institution.
Queensland Government.
Queensland Museum.
Rio de Janeiro Museo Nacional.
Royal Society.
Romaniei Institutului Geologic.
Smithsonian Institution.
Tokyo Imp. University.
Tuscany. Societa di Scienzi Naturali.
United States. Geological Survey.

Upsala. Geological Institute.
Vienna. K.K. Geologischen Reichsanstalt.
——. K.K. Naturhistorichsen Hofmuseums.
Victoria. Geological Survey.
Western Australia. Geological Survey.
Wisconsin Academy.
—— Survey.
Yorkshire Geological Society.

[*From the Author.*]

The Isles of Scilly. G. W. Zahn.

[*Purchased.*]

Palæontographical Society. Vol. LVIII.
London, Edinburgh, and Dublin Philosophical Magazine.

CURATOR'S REPORT.

ADDITIONS TO MUSEUM.

1912.

Specimen.	*Given by*
Orpiment	B. KITTO.
Scheelite Crystals	B. KITTO.
Orbicular Slate	W. COLENSO.

THE WILLIAM BOLITHO MEDAL,

which is provided for by a fund bequeathed to the Society for the purpose by William Bolitho, of Ponsandane, in 1895, has been awarded to the following members :—

1896. R. Etheridge, F.R.S.
1897. Howard Fox, F.G.S.
1898. J. H. Collins, F.G.S.
1899. F. W. Millett, F.R.M.S.
1900. Sir C. Le Neve Foster, F.R.S., etc.
1901. Thomas Clark.
1902. Dr. Richard Pearce, F.G.S.
1903. W. A. E. Ussher, F.G.S.
1904. J. D. Enys, F.G.S.
1905. Lady Warington Smyth.
1906. A. K. Barnett, F.G.S.
1907. U. Green, F.G.S.
1908. T. R. Polwhele, F.G.S.
1909. Rev. D. G. Whitley.
1910. Dr. G. J. Hinde, F.R.S., etc.
1911. C. Reid, F.R.S., etc.
1912. G. Barrow, F.G.S.

W. BOLITHO MEDAL ACCOUNT.

Dr.	£	s.	d.
March 29th, 1912—			
To Joseph Jennings for "Paper" on the Great North Lode of East Pool and Agar Mines .	10	0	0
July 31st, 1912—			
,, Gerrard and Co. for 1911 Gold Medal . .	12	10	0
November 12th, 1912—			
,, Balance	25	8	10
	£47	18	10

Cr.	£	s.	d.
October 31st, 1911—			
By Balance	30	3	1
February 15th, 1912—			
,, Dividend on £540 Great Western and Great Central Stock	8	17	9
August 15th, 1912—			
,, Ditto, ditto	8	18	0
	£47	18	10
November 12th, 1912—	£	s.	d.
By Balance	25	8	10

STATEMENT OF RECEIPTS AND EXPENDITURE FOR THE YEAR 1911–12.

Dr. *The Treasurer in Account with the Royal Geological Society of Cornwall.* **Cr.**

Receipts.

	£	s.	d.	£	s.	d.
October 31st, 1911—						
To Balance from 1911				19	19	5
November 12th, 1912—						
,, Ordinary Subscriptions and Arrears	42	0	0			
,, Subscription per His Royal Highness the Prince of Wales . . .	20	0	0			
,, One Year's Dividend on £1800 Midland Railway 2½% Debenture Stock . . . £45 0 0						
Tax at 1/2 . £2 12 6						
	42	7	6			
				104	7	6
				£124	6	11
November 12th, 1912—						
To Balance in hand				£17	3	3

Expenditure.

	£	s.	d.	£	s.	d.
November 12th, 1912—						
By Rates and Taxes	0	8	0			
,, Curator's Salary	42	7	6			
,, *Transactions*, Periodicals, Printing, and Stationery	19	2	9			
,, Fire Insurance Premium . .	3	15	0			
,, Coals and Gas	17	16	1			
,, Repairs to Buildings . . .	10	10	1			
,, Postages, Carriage, and Petty Disbursements	3	4	3			
,, Twelve copies of X 14 at 12/6 .	7	10	0			
,, Plans of East Pool, per J. H. Collins	2	10	0			
				107	3	8
,, Balance in hand				17	3	3
				£124	6	11

October 31st, 1912.

T. R. BOLITHO, *per pro Hon. Treasurer.*

LIST OF PAPERS

READ TO AND PUBLISHED BY THE SOCIETY.

1912.

President's Address. J. H. Collins, Esq., F.G.S.

China Clay and China Stone. J. M. Coon.

Note on Actinoceras Devonicans from Rope Haven. J. H. Collins, F.G.S.

On a Specimen of Orbicular Slate, a Specimen of Tilberthwaite. H. H. Thomas.

ON CHINA STONE, CORNISH STONE, OR PETUNTZYTE.

By J. M. Coon.

The rock known by the above name is a granite in which the orthoclase felspar of normal granite is largely replaced by plagioclase felspar, generally oligoclase; and biotite mica by muscovite or its varieties, sericite and gilbertite. The quartz is generally smoky, contrasting with the white felspar. Topaz and fluorspar are constant and characteristic components, their absence being regarded by the writer as evidence of alteration.

Less conspicuous constituents are magnetite, tourmaline and a manganous dendritic material spread over the joint faces and sometimes penetrating the minuter cracks of the rock.

If tourmaline be present in abundant and distributed quantities the rock will usually be much decomposed and kaolinised (Photos 13 and 14).

In its commercially valuable condition as a potter's raw material it occurs in small areas, is continuous with ordinary granite, but is easily recognised. The difference between that suitable and that unsuitable for pottery is so slight that the petrologist would considerably extend these areas.

Name.—The first two names at the head of the paper are sufficient if applied to the special quality of rock used for pottery, but they exclude very

closely allied rock, differing only in the colour of the mica and small quantity of ferrous or ferro-magnesian minerals contained. "Petuntzyte," suggested in 1878* by Mr. J. H. Collins, is free from this objection.

A descriptive name would be Plagioclase-Orthoclase-Muscovite-Granite, or Plagioclase Granite would be sufficient.

In the Table of Rocks—Acid Series, Rutley's "Granites and Greenstones"—*no mention is made of a granite* in which plagioclase felspar is dominant. This rock fills the *blank.*

Localities.—The principal occurrences are at:—

(*a*) Tregonning Hill—near Godolphin Hill—where it was first discovered by Cookworthy.

(*b*) Near Penryn.

(*c*) Near Goonbarrow in the parish of St. Austell.

(*d*) St. Stephen's in Brannel.

All in the County of Cornwall.

The most extensive quarries are at St. Stephen's in Brannel, the most characteristic rock being found in or adjacent to "Quarry Close" in that parish. This paper principally deals with the rock as there found.

Somewhat similar granite is found on parts of Dartmoor and forms a desirable building stone, but dark mica and ferruginous materials are present in such quantities as to render it unfit for potter's purposes.

Jersey stone is darker in appearance, and fluor and topaz are inconspicuous in the specimens seen by the writer.

* "The Hensbarrow Granite District," J. H. Collins F.G.S., 1878.

Quarry Face Sections.

Examining a quarry, from above downwards, it is found that the surface consists of peaty vegetable mould followed by several feet of stained and disintegrated granite fragments, locally known as "growan" (both are taken to the waste tips). Next below will follow portions much less stained, and compact but somewhat decomposed, known as "Buff Stone"; this formed the original article of pottery commerce. Under, again, are parts very white, often friable and much decomposed, known as "Dry White Stone"; from here downwards the rock gradually hardens and changes through "Mild White" and "Mild Purple" to "Hard White" and "Hard Purple" stone.

The "purple" tint is caused by the more or less conspicuous presence of fluorspar.

It is the last which now forms the most sought-for quality in the Potteries. Sharp demarcation does not exist, but the above order generally holds good. The following table gives the depths at which in the autumn of 1911 the various conditions of the rock were met at "Slip Quarry."

Vegetable Mould	Surface	2	feet
"Growan"	to	12	,,
"Buff Stone" and Friable "White Stone"	to	30	,,
Compact "Dry White"	to	50	,,
Mild White and Mild Purple	to	70	,,
Hard White and Hard Purple	to	120	,,

*

"Hard" stone is quite frequently found nearer the surface, but the best stone is generally deep.

The jointing and bedding are much like those of ordinary granite. In the "shallower" parts it is much disguised by disintegration and decomposition, but at greater depth the hard rock distinctly exhibits its character—approximately the "bedding" joints may be regarded as tangential and the "heading" joints as radial, having regard to general surface contour over long lines, the heading joints being in directions roughly at right angles to each other.

In each case the joint faces may be in actual contact or separated by inches and faulted.

The faulting, fractures and "slickensides" on contact faces show that movements have taken place and indicate directions. Some faces are so clean and even that they almost suggest planes of cleavage for the rock; many such can be found with wonderful regularity of angle between adjacent faces over an edge. In the quarries, the much greater ease with which the rock splits parallel to the bedding joints has led to the use of the term "grain of the stone," which is said to be parallel to this direction. That jointing and fissuring have occurred at different times is shown by repeated vein fillings and faults; the vein fillings are principally quartz, tourmaline and fluorspar, generally as mixed aggregates, in each case varying from mere films to several inches in thickness; when these veins communicate with

PHOTO NO. 1

Marshall's Quarry. Shows isolated column containing dark mica—in the surrounding rock the mica was white

PHOTO No. 2

Marshall's Quarry. Columnar appearance shown fairly well here

PHOTO No. 3

Marshall's Quarry. Widely extended face which was very flat and about 80 ft. × 80 ft.

PHOTO No. 4

Blocks of china stone (about $\frac{1}{5}$ full size). The upper part of rectangular block shows plentiful presence of fluorspar (interior of block) and in lower part its absence (from exterior of rock). Rectangular blocks are also well seen in Nos. 1 and 3

the surface, they are frequently much stained by oxidation products.

It is noticeable on many faces of joints not quite in contact that the fluorspar crystals stand out in sufficient relief to show the cubic form. In some quarries the joints extend continuously for long distances, the vertical ones frequently from the top to the bottom of the quarry, giving a columnar appearance (see Photos Nos. 1 and 2); they also extend laterally, and very flat even faces are now visible 80 ft.×80 ft. (see Photos Nos. 3 and 2). Masses of all dimensions will be found free, or apparently so, from fluor on the exterior, but distinctly speckled with it throughout the interior (see Photo No. 4.) Then again, distinct courses between joints will be either "white" or "purple" with only the joint separating; the demarcation is sharp and definite.

The phenomena attending the presence of fluorspar are complicated and sometimes apparently contradictory, but their study is of great importance if one would unravel the "life history" of this rock. Tourmaline and schorl rock are not nearly as prevalent as in china clay, china clay rock, or granite.

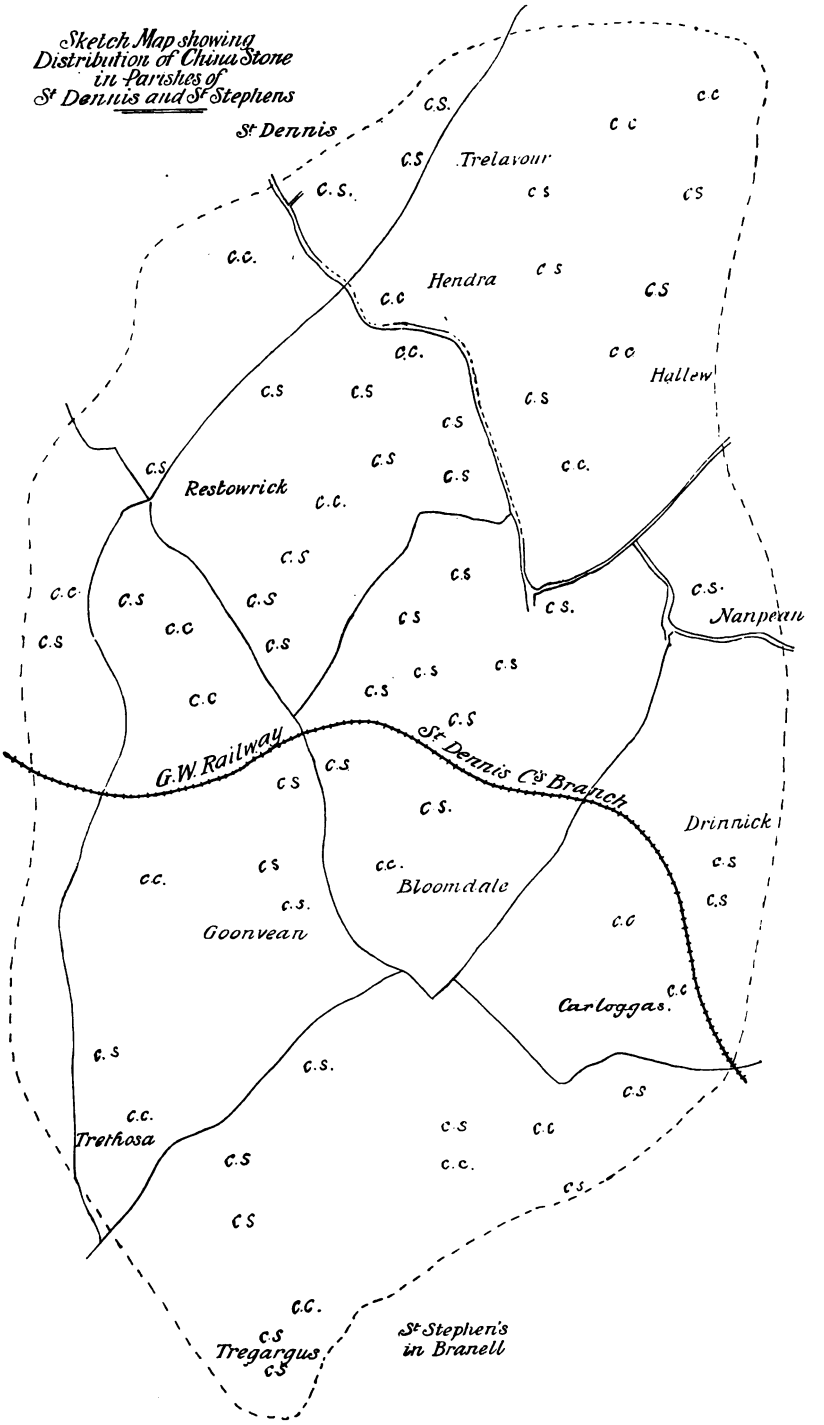
On the map appended hereto an attempt has been made to indicate the limits of the rock in the parishes of St. Stephen's and St. Dennis, the letters C.S. indicating occurrences of china stone, and C.C. parts worked for china clay. The china clay here is probably the result of decomposition of a similar rock.

It must be understood that the rocks of the indicated area are regarded as petrologically related without reference to their economic value.

PETROGRAPHICAL DESCRIPTION OF CHINA STONE.

"HARD PURPLE" is hard, hypidiomorphic, holocrystalline,—medium to coarsely granular rock—composed of FELSPAR—orthoclase, light cream colour—oligoclase, white. QUARTZ—often grey or smoky and very lustrous. MICA, muscovite—mostly white or very light yellow; also in rock not suitable for pottery, brown to dark brown and green: also gilbertite and sericite scarcely discernible without aid of microscope. FLUORSPAR—in purple-coloured specks and spots more or less abundant. "HARD WHITE" will vary from above in the absence of fluorspar; in the hand specimen, is scarcely otherwise distinguishable. "DRY WHITE" is the same rock in an advanced state of decomposition, being comparatively soft and friable. "BUFF STONE" is similar to dry white, but is coloured yellow or buff by the presence of oxidation products (Photo 20). "MILD PURPLE" and "MILD WHITE" are merely intermediate states.

The preponderance of the partly altered rock when the earlier descriptions were published was probably the cause of the altered rock being regarded as *normal;* deeper and more extensive workings have now shown that this is not the case.


Sketch Map showing
Distribution of China Stone
in Parishes of
St Dennis and St Stephens
St Dennis
Trelavour
Hendra
Hallew
Restowrick
Nanpean
G.W. Railway
St Dennis C.S. Branch
Drinnick
Bloomdale
Goonvean
Carloggas
Trethosa
Tregargus
St Stephen's
in Branell

extremely dark nodular rock inclusion consisting almost entirely of topaz (Photos Nos. 8 and 15) and mica; the latter possessed all the optical properties of zinwaldite (Photo No. 15).

The rock sections show it generally colourless or nearly so, without marked pleochromism; in basal sections, optical angle always wide: sections of the rock containing dark-coloured mica only differ from the foregoing description in slightly deeper colour and absorption. Gilbertite, as irregularly bounded aggregates, showing its characteristic fan-shaped arrangement with extinction practically parallel to the radiating lines of the fan (basal cleavage).

As inclusions the mica may have sericite (probably secondary), topaz and fluorspar, probably primary; the topaz in grains with rounded contours and sometimes partially penetrated by the mica lamellæ.

Topaz is another characteristic mineral, rarely idiomorphic, generally xenomorphic, much-fractured crystals, colourless and standing out in high relief and with many cavities and fluid inclusions (Photo No. 8). It is also present endomorphic in mica. The writer does not share the view that topaz is secondary in "China Stone." Possibly minute quantities of other minerals are present, but they are difficult to identify.

The foregoing descriptions of the minerals will apply to sections of each of the named conditions of the rock, except that as we leave the "hard purple" and reach the "dry white" the felspars become more and more decomposed, until kaolini-

sation is reached, as shown by the usual vermicular forms, the mica disintegrated and the fluorspar removed. In the "buff stone" stage, the fractures in the rock and its constituent minerals become filled with oxidation products. In the "dry white" stage magnetite and dendritic manganetic material are present.

Embedded in the rock are nodular masses varying from a few inches to nearly two feet in diameter, much finer in granules but consisting of similar minerals. The contact with the rock is fairly sharp, the crystallisation being continuous and the line of change from fine to coarser grain very narrow: no drusy cavities are found in them, their texture being uniform throughout; the mica is always dark. Their relation to the order of crystallisation of the rock is doubtful, but one is impressed with the idea that they preceded the enclosing rock, the suture-like contact surface, by partial solution and re-crystallisation. The surfaces are always curved. The workmen call them "wenns." They are carefully selected from the marketable stone.

SPECIFIC GRAVITY OF CHINA STONE
FROM NEAR "QUARRY CLOSE."

"DRY WHITE," much decomposed .	2·45–2·53
"HARD WHITE," fairly fresh . .	2·62–2·70
"HARD PURPLE" . . .	2·65–2·70

Reduction of sp. gr. on kaolinisation agrees with the result of same process in normal granite.

TABLE OF ANALYSES

Material	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	MnO	K_2O	Na_2O	H_2O	Fl	SO_3
1. Orthoclase	64·20	18·40						16·75				
2. Oligoclase	62·70	23·90			2·0				8·1			
3. Jersey Stone	78·15	13·46	0·38		0·55			3·74	3·80			
4. "	78·18	14·82	0·08		0·33	0·10		5·75		0 64	0·16	
5. Cornish Stone	73·39	16·30	traces		0·50	0·31	traces	7·66		1·25	0·74	
6. "	69·50	17·85	"		2·66	0·12	"	7·99		1·30	0·71	
7. "	71·66	18·77	"		1·70	0·35	"	6·66		0·91	0·14	
8. China Stone	71·70	17·45	0·16	0·07	1·24	0·53		4·08	2·52	2·18	0·13	nil
9. "	71·14	17·74	0·17	0·08	1·50	0·67		5·01	1·23	1·84	0·70	0·22
10. "	72·52	17·30	0·28	0·16	1·68	0·62		3·40	2·28	1·34	0·69	0 02

The above analyses were made by:—No. 3, Mr. Foulke Lowe, Chester. No. 4, H. Hughes, Connah's Quay. Nos. 5, 6 and 7, J. B. Hanway, Esq., Glasgow. (See "Hensbarrow Granite District," by J. H. Collins, F.G.S., 1878.) Nos. 8, 9, 10, by Bertram Blount, Esq., London, 1905.

PHOTO No. 5

Oligoclase in china stone. X 22. X nicols

PHOTO No. 6

Oligoclase endomorphic in orthoclase. X 10. X nicols

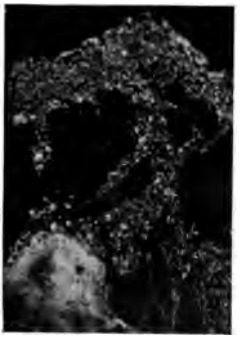


PHOTO No. 7

Corroded quartz crystal with sericite filling. X 107. X nicols

PHOTO No. 8

Topaz in china stone. X 18

PHOTO No. 9

Muscovite, sericite, and quartz — with fluorspar in the muscovite. X 107 —partly X nicols

PHOTO No. 10

Plumose gilbertite in china stone. X 20

PHOTO No. 11

Fluorspar traces of cube faces and with sericite intergrowth. X 22. X nicols

PHOTO No. 12

Oligoclase endomorphic in quartz. X 22. X nicols

PHOTO No. 13

Tourmaline in china stone, with partly idiomorphic Topaz on right-upper half. X 18

PHOTO No. 14

Tourmaline in china stone. X 18

PHOTO No. 15

Zinnwaldite, rare dark nodule in china stone. X 18

PHOTO No. 20

Felspar with fractures filled with oxidation products, buff china stone. X 20

PHOTO No. 21

Fluorspar in orthoclase, also sericite. X 22. X nicols

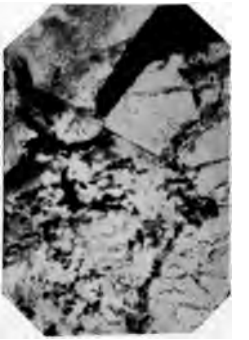


PHOTO No. 22

Dendritic iron in china stone. X 12

NOTE AND ILLUSTRATIONS OF A FOSSIL (*cf.* ACTINOCERAS DEVONICANS) FOUND AT ROPE HAVEN, ST. AUSTELL BAY, AND NOW IN THE TRURO MUSEUM.*

By J. H. Collins, F.G.S.

This fossil was found by the writer and the late Mr. Thos. Clark in the year 1889. Fig. 1, Plate I, is from a photograph showing the whole fossil, slightly more than one-third natural size. Fig. 2, Plate II, shows a portion of the lower end of the cone with indications of seven chambers, nearly full size. Fig. 3 is a transverse section of the same portion; and Fig. 4 a sketch of the large body chamber, each drawn about twice the natural size. Fig. 5 is a section of a fragment from the lowest portion of the cone, which has been drawn by the aid of the *camera lucida* under a magnification of six diameters. The fossilization is a little remarkable, for, while the septa have been obscured or destroyed by a succession of chemical changes, all the cavities of the original shell have been filled with deposits of secondary calcite and quartz; those portions which were partly or entirely of an organic nature, including the outer shell, have been pyritized, while the black filling of the outer body cavity is still more or less carbonaceous.

* For a fuller account, see *Journ. Roy. Inst. Corn.*, 1912, LVIII, pp. 36–39.

ON A SPECIMEN OF ORBICULAR SLATE.

Presented to the Museum by Mr. W. Colenso.

NOTE BY MR. H. H. THOMAS.

THE specimen sent by Mr. Collins has been sliced in two directions (E. 9599) and it has been compared with specimens already in our* collections (E. 163), one of which appears to have escaped the shearing which the so-called slate has undergone.

The original rock seems to have been clastic in character, but owing to the extreme degree of silicification almost all trace of the original structure has disappeared.

The curious spheroidal structures observable in the slate are almost certainly due to some concretionary action, probably connected with the silicification. That this concretionary action took place previous to the stresses which gave rise to the cleavage is certain from the fact that in the uncleaved portions of the rock the concretions are spheroidal and not drawn out to any extent, while in the slates their outline is markedly elliptical. This slate is quarried from a depth of 300 feet at Tilberthwaite, Coniston, Westmorland.

* Jermyn Street Museum.

TRANSACTIONS

OF THE

Royal Geological Society

OF

CORNWALL.

TRANSACTIONS

OF THE

Royal Geological Society

OF

CORNWALL.

INSTITUTED FEBRUARY 11th, 1814.

VOLUME THE THIRTEENTH.

"Geology in the magnitude and sublimity of the objects of which it treats, undoubtedly ranks, in the scale of the sciences, next astronomy: like astronomy, too, its progress depends on the continual accumulation of observations carried on for ages."—SIR JOHN HERSCHEL, Bart.

PENZANCE:
SOLD AT THE MUSEUM OF THE SOCIETY.
1914.

Royal Geological Society of Cornwall.

THE ONE HUNDREDTH

ANNUAL REPORT

ETC.

PENZANCE.

1914.

VOL. XIII. 2 P

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Vice-Patron:

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The Secretary requests the favour of his being informed of any inaccuracies in the foregoing lists.

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THE ANNIVERSARY ADDRESS OF THE VICE-PRESIDENT,

J. H. COLLINS, Esq., F.G.S.

To the General Meeting, November 11th, 1913.

As one of your Vice-Presidents it falls to me at very short notice to occupy this chair in the unavoidable absence of your President, Lord St. Levan. Under these circumstances you will not expect anything of the nature of a Presidential Address from me to-day. But being here I should like to make a few remarks on a matter of very considerable importance. Next year we shall be one hundred years old, and it will be right that we should take steps to celebrate the occasion fittingly; I do not doubt that our younger brethren the Royal Institution of Cornwall and the Royal Cornwall Polytechnic Society, at whose prosperity we heartily rejoice, will help us to make a worthy celebration, and I hope the town of Penzance will rise to the occasion as it did thirty-five years ago when we celebrated the centenary of Sir Humphry Davy's birth. My friend Mr. Barnett, who took a prominent part in the arrangements, will remember that he and I journeyed to London and were very kindly received at the Royal Institution, where Davy made his most important discoveries, by Professor Tyndall and his wife. The Professor lent us from the Institution several pieces of apparatus which Davy had used in his invention of the Safety Lamp and in the preparation of the alkali metals, and these were exhibited in this hall together with the safety lamp which had been presented to the Society by Davy himself. Mr. Barnett, who seems now to be the permanent Mayor of Penzance, will, I am sure, do everything in his power to make our next year's celebration a success, and, of course, I shall

be glad to do what I can if I am still on this planet, though I shall then be more than seventy-three years of age, and resident a good way from Penzance.

Our members' roll and our long list of Presidents include many distinguished names; our fourteen volumes of *Transactions* are valued wherever geological science is studied the world over, and in spite of the temptation nowadays to seek publicity in the *Transactions* of Societies having a wider circulation than ours, I see no reason to fear that the Society's second century will be less useful than its first has been.

We have with us to-day Mr. J. B. Hill, who has done such good work, with his colleagues, in the geological re-survey of Cornwall and West Devon, which was brought about mainly by the representations of this Society and the efforts of Mr. Howard Fox and other distinguished members. The survey has been in progress for ten years or more; no fewer than thirteen volumes of *Memoirs* have been published, and I am glad to say that the surveyors have constantly and generously recognized the work of members of this Society over a period of a century and a quarter or more. For myself I am proud to find my name and work referred to frequently, though not always with entire approval, in eleven of the thirteen volumes.

A good many years ago one of our members, Mr. Wm. Bolitho, bequeathed a considerable sum of money, the interest of which was to cover the cost of a gold medal, to be awarded according to the judgment of the Council to some worker in the cause of Cornish Geological Science. The surplus of that fund is awarded from time to time in the form of Bolitho prizes for suitable contributions to this Society's *Transactions*. Two such prizes have already been awarded for original contributions of merit to Capt. Jos. Jennings, of East Pool Mine, and to Mr. Jos. Coon, of St. Austell, and their papers have already appeared in our *Transactions*. These gentlemen have also been elected as Associates of the Society.

To-day, as I have said, we welcome Mr. Hill, not merely the few of us who are here present, but the many who are present with us in spirit. The Council has awarded the Bolitho Gold

Medal for this year to Mr. Hill in recognition of the excellent work he has done in connection with the survey, and has at the same time elected him an Honorary Member of the Society.

Mr. Hill, I have now the pleasure of handing you this well-earned Bolitho Medal, the Society desiring to do honour to itself and to you by the award.

REPORT OF THE COUNCIL

To the Annual General Meeting, November 11th, 1913.

THE Council are pleased to be able to report that the premises and collections of the Society are in good order. Some valuable and interesting specimens have been added to the museum during the year, and are mentioned in the report of the Curator. The Library has continued to increase at about the normal rate of 320 volumes and parts. The value to the County of such an exhaustive collection of information on all matters connected with Geology and allied subjects can hardly be overestimated.

The Council have during the year awarded a prize of £10 out of the William Bolitho Prize Fund to Mr. J. M. Coon for his paper on "China Stone and China Clay," which was published in the last number of the *Transactions*.

They are pleased to note that as the offer of these prizes is becoming more widely known, it has produced valuable results in stimulating scientific research.

They have decided to award the William Bolitho Medal for the year to Mr. J. B. Hill, F.G.S., in recognition of his valuable work for Cornish Geology in connection with the new Survey.

The arrangements for celebrating the centenary of the Society in 1914 are not yet sufficiently advanced for any definite pronouncement, but they hope to have matters arranged at an early date, and trust to receive the cordial support of the members in carrying them out.

LIBRARIAN'S REPORT.

1913.

THE Librarian acknowledges, with thanks, the receipt of publications from the following:—

American Philosophical Society.
—— Academy of Arts and Sciences.
—— Geographical Society.
—— Institute of Mining Engineers.
Australian Association.
British Association.
Canada. Department of Mines.
——. Royal Society.
Canadian Institute.
Cape of Good Hope. Geological Survey.
Cincinnati. Society of Natural History.
Colorado Scientific Society.
Connecticut Academy of Arts and Sciences.
Cornwall Royal Polytechnic Society.
——. Royal Institution.
Dorpat. Naturforscher Gesellschaft bei der Universitat Jurjew.
Dublin Royal Society.
Edinburgh Royal Society.
—— Geological Society.
Elisha Mitchell Scientific Society.
Geological Survey.
Geological Society.
Geologists' Association.
Glasgow Geological Society.

India. Geological Survey.
Indiana. Academy of Science.
Iowa Geological Survey.
Leicester Literary and Philosophical Society.
Liverpool Geological Society.
Manchester Geographical Society.
Mexico. Instituto Geológico.
——. Sociedad Geologica.
Missouri. Bureau of Geology.
Montana. University.
New York Academy of Sciences.
New South Wales. Geological Survey.
——. Royal Society.
New Zealand. Department of Mines.
Normandy. Société Géologique.
North of England Institute of Mechanical and Mining Engineers.
Peru. Cuerpo des Ingeniores de Minas.
Philadelphia. Academy of Natural Sciences.
Plymouth Institution.
Queensland Government.
Rochester. Academy of Science.
Royal Society.
Romaniei Institutului Geologic.
Smithsonian Institution.
Tokyo Imp. University.
Tuscany. Societa di Scienzi Naturali.
United States. Geological Survey.
Vienna. K.K. Geologischen Reichsanstalt.
Victoria. Geological Survey.
Western Australia. Geological Survey.
——. Department of Mines.
Wisconsin Survey.

[*From the Author.*]

The Sp. Gravity of some Saline Solutions. J. Y. Buchanan, F.R.S.

Topaz and Beryl from Lundy Island. McLintock and Hall.

Japanese Coals. C. Iwasaki.
The Older Palæozoic Succession of the Duddon Estuary. J. F. N. Green.
Appennino Meridionale. F. Sacco.
Geotermica Applicata. ,,
La Courbe Hypsographique ,,
Fenomoni Filoniani e Pseudo-filoniani. F. Sacco.
Meteoric Stones, Aztec Arizona. W. M. Foote.
The Age of the Earth. J. Joly, F.R.S.
Fossil Flora and Geological Climate. A. G. Nathorst.
Submerged Forests. C. Reid, F.R.S.

[*Purchased.*]

Palæontographical Society. Vol. LVIII.
London, Edinburgh, and Dublin Philosophical Magazine.

CURATOR'S REPORT.

ADDITIONS TO MUSEUM.

1913.

Specimen.	*Given by*
Orbicular Slates from Tilberthwaite, Kendal .	W. COLENSO.
Alluvial Tin, Knyls River, Cape Colony . .	F. H. UREN.
Cassiterite in Quartz ,, ,, (three specimens)	,,
Cassiterite in Granite, Zaæplaats Mine, Transvaal	,,
Cassiterite with Chalybite, Rooiberg Mine, Transvaal	,,
Smaltite, Drummond Mines, Cobalt . . .	T. WILLIAMS.

THE WILLIAM BOLITHO MEDAL,

which is provided for by a fund bequeathed to the Society for the purpose by William Bolitho, of Ponsandane, in 1895, has been awarded to the following members :—

1896. R. Etheridge, F.R.S.
1897. Howard Fox, F.G.S.
1898. J. H. Collins, F.G.S.
1899. F. W. Millett, F.R.M.S.
1900. Sir C. Le Neve Foster, F.R.S., etc.
1901. Thomas Clark.
1902. Dr. Richard Pearce, F.G.S.
1903. W. A. E. Ussher, F.G.S.
1904. J. D. Enys, F.G.S.
1905. Lady Warington Smyth.
1906. A. K. Barnett, F.G.S.
1907. U. Green, F.G.S.
1908. T. R. Polwhele, F.G.S.
1909. Rev. D. G. Whitley.
1910. Dr. G. J. Hinde, F.R.S., etc.
1911. C. Reid, F.R.S., etc.
1912. G. Barrow, F.G.S.
1913. J. B. Hill, F.G.S.

W. BOLITHO MEDAL ACCOUNT.

Dr.	£	s.	d.	Cr.	£	s.	d.
September 16th, 1913—				November 12th, 1912—			
To Gerrard and Co. for 1912 Medal	12	10	0	By Balance	25	9	1
November 6th, 1913—				February 15th, 1913—			
,, J. M. Coon for "Paper" on China Clay and China Stone	10	0	0	,, Dividend on £540 Great Western and Great Central 3½ % Stock	8	18	0
November 11th, 1913—				August 15th, 1913—			
,, Balance	20	15	1	,, Ditto, ditto	8	18	0
	£43	5	1		£43	5	1
				November 11th, 1913—	£	s.	d.
				By Balance	20	15	1

STATEMENT OF RECEIPTS AND EXPENDITURE FOR THE YEAR 1912–13.

Dr. *The Treasurer in Account with the Royal Geological Society of Cornwall.* **Cr.**

Receipts.

	£	s.	d.	£	s.	d.
November 12th, 1912—						
To Balance from 1912				17	3	3
November 11th, 1913—						
,, Ordinary Subscriptions and Arrears	44	2	0			
,, Subscription per His Royal Highness the Prince of Wales . . .	20	0	0			
,, One Year's Dividend on £1800 Midland Railway 2½ % Debenture Stock . . . £45 0 0						
Less Tax . . £2 12 6						
	42	7	6			
,, Sale of *Transactions* . . .	3	4	0			
,, Mr. J. M. Coon for Cast of Plates .	5	0	0			
				114	13	6
				£131	16	9
November 11th, 1913—						
To Balance in Treasurer's hands				£25	6	6

Expenditure.

	£	s.	d.	£	s.	d.
November 11th, 1913—						
By Water Rate	0	8	0			
,, Curator's Salary	42	7	6			
,, *Transactions*, Periodicals, Printing, and Stationery	23	4	1			
,, Fire Insurance Premium . .	3	15	0			
,, Coals and Gas	13	11	2			
,, Repairs to Buildings . . .	10	0	0			
,, Painting Premises	10	0	0			
,, Postages and Petty Disbursements .	1	2	6			
,, Palæontographical Society, Two Years' Subscriptions	2	2	0			
				106	10	3
,, Balance in hand				25	6	6
				£131	16	9

October, 1913.

T. R. BOLITHO, *per pro Hon. Treasurer.*

LIST OF PAPERS

READ TO AND PUBLISHED BY THE SOCIETY.

1913.

Vice-President's Address. J. H. Collins, Esq., F.G.S.

The Early Tin Trade of Cornwall according to Strabo's Geography. Rev. D. Gath Whitley.

On the Geological History of William's Lode in King Edward Mine, Camborne. P. Beresford Lees.

THE EARLY TIN TRADE OF CORNWALL ACCORDING TO STRABO'S GEOGRAPHY.

By Rev. D. Gath Whitley.

The question of the earliest exportation of Tin from Cornwall is beset with difficulties on all sides. Down to the middle of the last century it was taken for granted that the Phœnicians regularly visited Cornwall in the days of their maritime prosperity, and that they exported the tin from our shores to their Mediterranean settlements, whence it was conveyed to the commercial centres of the East. A reaction against these opinions has, however, lately taken place. It is now affirmed that the Phœnicians never came to Cornwall. If the Cassiterides ever really existed they are placed in Vigo Bay in North-west Spain, and not in Cornwall; and so certain are the holders of these new views that they are absolutely correct, that they do not hesitate to declare with genuine modern impatience that those who maintain the old opinions are hopelessly behind the times, and do not deserve to be noticed. When *reasons* are asked for, and *proof* is demanded *why* the western portion of Great Britain cannot be the Cassiterides, we are presented with a series of statements which are, to

say the least, peculiar. Attacks are made—which are wholly unsupported by evidence—on the veracity of ancient historians. Side issues, which have nothing to do with the main question, are dragged into the controversy. Assumed "contradictions," which may be found in every work of ancient history or geography, are paraded in grotesque array. So-called "difficulties," which have long ago been answered, are continually brought forward. "Improbabilities," which exist only in the mind of the inventor, are presented with emphatic dogmatism. The evidence for the Traditional view is never given a fair hearing, and the arguments of the defenders of the view that our Cornish peninsula was visited by the Phœnicians in their trade for tin are either wholly ignored, or declared to be utterly "old-fashioned" and "out of date"!

In a former paper to this Society,* I discussed the statements of Herodotus relating to the position of the Cassiterides. I showed that Herodotus declared that *all* the tin brought to the eastern part of the Mediterranean came from the Cassiterides. He did not know the precise situation of the Cassiterides, but he placed them in the great ocean to the north of Europe, into which flowed the great rivers of Northern Europe. He further stated that tin and amber came from the same northern regions. All this clearly demonstrated that Herodotus believed that the Cassiterides lay somewhere

* *Transactions of the Royal Geological Society of Cornwall*, Vol. XIII, Part VIII, 1912.

in the North Sea or in the German Ocean. I am not acquainted with any answer to these arguments. I also stated that Himilco the Carthaginian voyaged to the Northern Sea, and visited certain islands which produced tin and lead, and as these islands were too far north to have any connection with Spain, they must have been situated in the seas of Britain.

I shall now discuss the testimony of Strabo concerning the position and tin trade from the Cassiterides. In his most important statement relating to these islands, he speaks as follows :—

"The Cassiterides are ten in number, and lie near each other in the ocean towards the north from the haven of the Artabri. One of them is desert, but the others are inhabited by men in black cloaks, clad in tunics reaching to their feet, girt about the breast and walking with staves, thus resembling the Furies we see in tragic representations. They subsist by their cattle, leading for the most part a wandering life.

"Of the metals they have tin and lead, which, with skins, they barter with the merchants for earthenware, salt, and brazen vessels. Formerly the Phœnicians alone carried on this traffic from Gades, concealing the passage from everyone; and when the Romans followed a certain shipmaster, that they also might find the market, the shipmaster, from jealousy, purposely ran his vessel upon a shoal, leading on these to follow him into the same destructive disaster; he himself escaped by means of

a fragment of the ship, and received from the State the value of the cargo he had lost. The Romans, nevertheless, by frequent efforts, discovered the passage, and as soon as Publius Crassus, passing over to them, perceived that the metals were dug out at a little depth, and that the men were peaceably disposed, he declared it to those who already wished to traffic in this sea for profit, although the passage was longer than to Britain. Thus far concerning Iberia, and the adjacent islands."*

In another passage Strabo says :—

"Northward and opposite to the Artabri are the islands denominated the Cassiterides, situated in the high seas, but under nearly the same latitude as Britain."†

From these quotations we gather for certain that Strabo believed concerning the Cassiterides :—

First, that long before his time, the Phœnicians from Gaddir (i.e. Cadiz) regularly visited the Cassiterides for purposes of trade. This trade was *entirely* in the hands of the Phœnicians, who kept the route to the Tin Islands secret. Wherever, therefore, the Cassiterides were situated, the Phœnicians regularly came to them.

Secondly, in order to reach the Cassiterides the Phœnicians from Cadiz always went by *sea*. It was by *sea* from Cadiz that the Phœnicians reached the Cassiterides, and it was by *sea* that they always brought the precious metals from the Tin Islands

* *Geography*, Book III, chap. v.
† *Ibid.*, Book II, chap. v.

to Cadiz (i.e. Gaddir). Now, if the Cassiterides were in Gallicia in North-western Spain, the Phœnicians would have brought the tin to Cadiz by *land* and not by *sea.* It is necessary to understand this clearly. The Phœnicians worked mines of lead, iron, silver, gold, and mercury in nearly every part of Spain, and these metals were brought to Cadiz and to the Phœnician settlements on the southern and Mediterranean coasts of Andalusia by *land.* There was therefore a *land transit* of metals from all parts of Spain to the seaports, so that Spain was crossed in all directions by land routes for commerce. Mr. Elton has well described the immense wealth of Spain in the precious metals in the following eloquent words, which bear directly upon the present discussion :—

"It must always be remembered that Spain was the Mexico of the ancient world. The Tagus rolled gold, and the Guadiana silver; the Phœnician sailors were said to have replaced their anchors with masses of silver, for which they had no room on board, and the Iberians to have used gold for mangers and silver for their vats of beer. The western and northern coasts were equally rich : a mountain of iron ore stood near Bilbao, and the whole coast from the Tagus to the Pyrenees was said to be 'stuffed with mines of gold and silver, lead and tin.'

"'genetrix hæc ora metalli
'Albeutis stanni.'*

* *Avien-Deser.* Orb. 741.

"The moorlands were full of tin-pebbles; the river gravels mixed with broken strings and branches of tin, which the Iberian girls were able to win by light 'stream-work,' washing the ore from the soil in wicker cradles; and, as in Cornwall, the tin was often mixed with gold, and the lead with silver. We learn the ancient wealth of the country from the reports of Greek travellers, and from the Romans who inherited the riches of Spain, when the power of Tyre and the careless magnificence of Carthage had passed away, and before the mineral deposits had been very sensibly diminished." *

The whole of Spain, therefore, was traversed by inland routes by which minerals were brought to the southern and western coasts, and, had the Cassiterides existed in the north of Spain, the tin would certainly have been brought to Gaddir by *land* and not by *sea*, as Strabo declares. The Phœnicians, who brought trade products across the whole of Europe by *land* to their settlements on the shores of the Black Sea, would think but little of the difficulties of carrying precious metals across the mountains of Spain and Portugal.

Thirdly, in what direction from Gaddir (Cadiz) was the voyage to be taken to reach the Tin Islands? Not to the south, for, although the Phœnicians had fishing stations on the north-western coast of Africa, and also brought large quantities of fish from the shoals of Arguin—which is probably the richest fishing locality in the world

* *Origins of English History* (1st Edition), pp. 9–11.

—no tin was ever brought from the south to the Phœnician settlements in Spain. It was to the north that the voyage was always undertaken from Gaddir (Cadiz) to bring back tin. Our gaze is always turned by the ancient geographers to the extreme north-west of Spain, that is to the province of Gallicia, and to the neighbourhood of Cape Finisterre, which in ancient times were called the Coasts of the Artabri. Now, many modern theorists declare that the Cassiterides were three groups of small islands, which are situated close to the shore of Gallicia, and lie at the entrance of the Bays of Vigo, Arosa, and Pontevedra.* They are most insignificant islets, and no tin is raised in them, and no records exist of any tin mining having been carried on in them in ancient times. †

Fourthly, Strabo says that the Cassiterides lay "in the ocean," and in "the high seas" to the "north of the haven of the Artabri." It is admitted by all authorities that the haven of the Artabri was Corunna, and a glance at the map will show us that there are *no islands whatever* in the ocean north of Corunna until we reach the Scilly Isles and the coasts of Britain. The islands off the Gallician coast near Vigo, which many modern theorists consider to be the Cassiterides, lie far to the *south* of Corunna and not to the *north* of that seaport, so that unless we are to imagine that when Strabo

* See *The Dolmens in Ireland*, by W. C. Borlase, Vol. III, pp. 12–32.

† There used to be only one very insignificant tin mine working in these districts. I do not know if it still exists.

says "north" he means "south"—which is hardly a scientific use of the imagination—they cannot possibly have been those Tin Islands to which this ancient geographer refers.

Let us look at the matter a little more closely. According to the precise statements of Strabo, the Cassiterides lay "in the ocean" and "in the high seas." This means, if words have any signification whatever, that the Tin Islands were situated far out in the ocean, and at a great distance from the Spanish shores. But the insignificant islands in Vigo Bay and the neighbouring bays are *close to the shore*, and at the entrance to land-locked harbours! * Again, let us take another term that Strabo uses to show the position of the Cassiterides. He says that they were situated in "the high seas." Everybody knows that these words signify the depths of the ocean, far away from any land whatever. "Piracy on the high seas" means committing depredations in the lonely heart of the ocean, and does not signify robbing vessels close to the shore and in land-locked harbours.

In order to make still clearer the position of the Cassiterides, Strabo further states that while these islands lay "in the high seas," they were "under nearly the same latitude as Britain." This means that they were nearly as far north as Britain itself. It is therefore quite certain that islands which lay in the ocean near the coast of Britain could not,

* There is a good map of the islands in Vigo Bay and the adjacent harbour in *Britain B.C.*, by Henry Sharpe.

by any possibility, be placed on the shores of Spain. I am not concerned to discuss the exact correctness of all Strabo's attempted measurements, but it is plain that he considered that Britain and the Cassiterides lay in the ocean near each other.

Fifthly. Something still more decisive as to Strabo's opinion concerning the situation of the Tin Islands is to come. He tells us that Publius Crassus, having made the passage to the Cassiterides and having seen their wealth, made it known to all who wished to traffic in these seas, adding these significant words: "although the passage (to the Cassiterides) was longer than that to Britain."

Now here is a statement which is absolutely decisive. Strabo is speaking of the character and length of the voyage from Cadiz (i.e. Gaddir) to the Cassiterides, and he says that this voyage was *longer* than the voyage from Cadiz to Britain. This makes it absolutely impossible for the Cassiterides to have been situated in Vigo Bay, or off the neighbouring coasts of Spain. A glance at the map will show in an instant the impossibility of such an idea. Vigo Bay with its adjacent islands is only about *half* the distance from Cadiz to Britain, and by no possible methods of geographical alteration of the map of Europe can it be placed at the same distance from Cadiz as the British Islands. The Tin Islands therefore mentioned by Strabo must have been situated in the northern

seas, at least as far north as Britain. Some difficulty may seem to arise from the statement that the voyage to the Cassiterides from Cadiz was *longer* than the voyage to Britain. This, however, may be explained by the character of the navigation in those days. Ships from Gaddir (i.e. Cadiz) sailing to the British seas would keep inshore, and would sail close to the coasts of Portugal and Northern Spain. Then they would coast the western shores of France and cross the English Channel to the coasts of Sussex. From this point they would turn westwards along the southern shores of Britain, until the Tin Islands in Western Damnonia (i.e. Cornwall and the Scilly Islands) were reached. This seems to have been the course followed by Pytheas in his voyage of discovery to the north from Massilia.* From the western extremity of Brittany, he sailed up the English Channel until he was opposite to Kent, when he crossed over to Britain. All this shows that the Tin Islands of Strabo must have been situated in the Britannic seas.

This is still more evident when Strabo tells us that Publius Crassus "passed over" from Spain to the Cassiterides. What did Publius Crassus "pass over"? Certainly not the few miles which separate the islands at the entrance of the harbour of Vigo from the mainland. Publius Crassus passed over the "passage" to the Cassiterides which the Phœnicians tried to conceal, and which was longer than

* *Circa* 330 B.C.

the passage (i.e. voyage) from Gaddir (i.e. Cadiz) to Britain.

Unless Strabo's words, therefore, are entirely untrue from beginning to end, and unless he means something entirely different from what he says, we are compelled to conclude that he believed the Cassiterides to lie somewhere in the neighbourhood of Britain.

It is objected that it is said that the Cassiterides were "over against Spain"; but this is quite in harmony with the prevailing idea in the days of Cæsar,* Pliny, and Strabo, that Britain lay "opposite," and "over against" Spain. Even so late as Bede's day, Britain was spoken of as "facing Spain," † although at a considerable distance. Tacitus also says of the country of the Silures, which was a part of South Wales, that it was situated "opposite to Spain."‡

Consequently, the term "over against Spain" might well be applied to the Cassiterides, although they were situated in the Britannic seas.

Another view has been put forward that when Strabo says the passage to the Cassiterides was longer than that to Britain, he means that it took more time to go to Vigo Bay from Massilia than it took to make the *overland* journey from Massilia (Marseilles) to Britain. Also when Publius Crassus taught traders how to "make the passage" Strabo

* *Commentaries*, Lib. V, cap. XIII.
† *Ecclesiastical History*, Book I, chap. I.
‡ *Agricola*, cap. XI.

is speaking of the voyage from Massilia (Marseilles)* along the coasts of Spain and Portugal.

This explanation is absolutely impossible. If we read Strabo's own words, and examine what he really *does say*, we shall be surprised that it ever was brought forward. Strabo is not speaking of any voyage from Massilia to Cadiz, of any overland journey from Massilia through Gaul to Britain. He has nothing whatever to say about such things. He is describing one voyage "or passage" only, and that is the voyage from Cadiz (i.e. Gaddir) to the Cassiterides. What he really *does* say is, that the voyage (or "passage" or, more properly, "sea route") from Cadiz to the Cassiterides was longer than the sea passage which had to be navigated in going from Cadiz to Britain. There is nothing here about Massilia or Gaul, and an examination of Strabo's *exact words* in the original will at once decide the question. It is useless to attempt to avoid the inevitable conclusion. Strabo certainly places the Cassiterides in the seas of Britain, and by no logical legerdemain can they possibly be placed in Vigo Bay.

By way of a compromise M. de Mortillet places the Cassiterides off the coast of Brittany, although *why* this situation has been chosen I cannot tell. M. Hans Hildebrand † places them in the ocean north of Corunna Bay, where there are at present no islands! Mr. W. C. Borlase thinks that *both*

* Elton's *Origins of English History*, p. 19.

† *Sur la Situation des Cassiterides.* Paper read at the International Congress of Anthropology at Stockholm, 1876.

Cornwall and Gallicia were sources of tin,* and says in accents of despondency: "The more we attempt to give the Cassiterides a definite geographical position, the more these islands fade into the fabulous regions of the hazy sundown." But all these statements are in direct contradiction to the plain words of Strabo, who declares most emphatically that the Cassiterides were in the same latitude as Britain,† and says most clearly that the voyage from Gaddir (i.e. Cadiz) to the Cassiterides was longer than the voyage from Cadiz to Britain. Words could not more definitely place the Cassiterides in the seas of Britain than those used by Strabo.

The voyage of Pytheas to the British seas and to the German Ocean which Strabo so adversely criticized furnishes a further argument. The object of that voyage was commercial, and its main purpose was to discover the source from which the Phœnicians of Gaddir obtained their tin.‡ Pytheas passed along the whole western coasts of Spain, Portugal, and France, and sailed northwards as far as Lapland, but obtained no definite information as to the Tin Islands. Had the Cassiterides lain in Vigo Bay, as some authorities imagine Strabo to have asserted, Pytheas would have proceeded no further than the coasts of Gallicia.

* *The Dolmens of Ireland*, Vol. III, p. 1232.

† *Geography*, Book II, chap. v, par. 15.

‡ See *Early Man in Britain*, by W. Boyd Dawkins, pp. 477–8, and Elton's *Origins of English History*, chaps. I, II.

Another statement made by Strabo, in which he mentions the Tin Islands, is as follows :—

"Fronting Europe lie the islands which we have mentioned. Without the pillars of Hercules, Gadiera (i.e. Cadiz), the Cassiterides, and the Britannic Isles."*

It would seem from this that the situation of the Cassiterides is not fixed, but a glance at the whole of the sentence leads us to a different conclusion. Strabo is referring to what he has said a short time before, in which he says that the Cassiterides are in the same latitude as Britain, and that they lie in the high seas opposite the haven of the Artabri, that is, Corunna. The two statements are perfectly similar. The sea trade from Cadiz, however, was not in Strabo's time the same as it had been in the days of Phœnician supremacy.

In another passage Strabo says :—

"The tin is not found upon the surface as authors commonly relate, but it is dug up; and it is produced both in places among the barbarians who dwell beyond the Lusitanians, and in the islands Cassiterides, and from the Britannic Islands it is carried to Marseilles. Among the Artabri, who are the last of the Lusitanians towards the north and west, Posidonius tells us that the earth is powdered with silver, tin, and white gold, that it is mixed with silver, the earth having been brought down by the rivers; this the women scrape up with spades

* *Geography*, Book II, chap. v, par. 30.

and wash in sieves woven after the fashion of baskets." *

Now it will be noticed, in examining this passage, that Strabo is relating the discovery of tin in different regions. He says (following Posidonius) that tin is found in different districts in the west of Europe, such as Britain, the Cassiterides, and in the north-west of Spain, that is, in Gallicia, or "the coasts of the Artabri." The first part of the paragraph quoted refers to the two former regions, and it will be observed that Strabo unites Britain and the Cassiterides, clearly distinguishing them from the Spanish tin regions. It has even been supposed that the *whole* of the passage is merely an account of the tin districts in Belerium,† which are described at length by Diodorus Siculus when he gives an account of the Cornish tin mines in Belerium, and of the island of the Iktis.‡ I offer no opinion on this point, but I further examine the lengthy statement of Strabo just quoted.

It will be noticed that the *exact* position of the Cassiterides is not given by Strabo in the passage quoted. These Tin Islands are, however, clearly distinguished from the regions of the Artabri, which are described in a later passage. He also distinguishes *two* ways of obtaining tin. The *first* is that tin is dug up from mines, and this is the manner of obtaining tin in Britain and in the Cas-

* *Geography*, Book III, chap. II, par. 9.
† *Quarterly Review*, Vol. 159, No. 318, p. 430.
‡ Diodorus Siculus, V, 22.

siterides. Further on Strabo describes (following Posidonius) how tin is found on the *surface* in North-western Spain, and that it is washed out of the sands brought down by the rivers. Here, therefore, are two entirely different tin regions described, in which the tin is obtained in two entirely different ways. In Britain and in the Cassiterides it was dug from veins, in Spain it was *alluvial* and brought down by rivers. Clearly, therefore, the Cassiterides cannot have been in Spain, but must have been situated in an altogether different region, that is, in the seas of Britain.

Finally, the term "Tin *Islands*" is perfectly correct. It includes not merely the islands in which the tin was dug up, but also the islands in which it was *sold*. These last were scattered islets around the coast of Western Britain, such as St. Michael's Mount and Drake's Island in Plymouth Sound. These places the Phœnicians chose for the purchase of tin from the natives, because of their security. Possibly they voyaged to Ireland also, for Professor Boyd Dawkins has shown that tin was mined in Wicklow in very ancient times.* In the voyage to Ireland they doubtless touched at the Scilly Isles, and all these islands in addition to Cornwall and Devon were included in the term Cassiterides.

* *Early Man in Britain*, pp. 403, 467.

ON THE GEOLOGICAL HISTORY OF WILLIAM'S LODE IN KING EDWARD MINE, CAMBORNE.

BY P. BERESFORD LEES.

(Communicated by T. C. F. HALL).

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KING Edward Mine is a part of South Condurrow Mine carried on by the Camborne School of Mines for instructional purposes. The lodes occurring in this mine are the Great Flat Lode, Engine, William's, South, and West Basset Lodes, as well as several other, smaller, veins which have not been given special names (see section, Plate I).

The only one of these at present being worked to any extent is William's Lode, which is the subject of this paper.

GENERAL DESCRIPTION AND TECTONICS.

The junction between the killas and the granite occurs at a depth of between twenty and thirty fathoms below the surface in the northern part of the mine, where it may be examined in several places in the

adit level; for the southern portion no observations have been made by the author and no data could be obtained from the various mine plans examined. It is said, however, by Captain Kit Bennetts, to dip toward King's shaft at about 30°, at which angle it is shown somewhat diagrammatically in the section (Plate I).

William's Lode, formerly called the Middle Lode and referred to under that name in the Survey Memoir on the district, forms one of a series of small lodes dropping into and faulting the Great Flat Lode on the south-east side of the Carn Brea granite mass. It strikes somewhat north of north-east and dips at about 85° to the south. The parts of the lode at present being worked are situated in the granite, and are either vertical or dipping steeply to the south. There seems to be no evidence, in the working places at present accessible, for the northerly dip shown in the section as occurring between the adit and the 10-fathom levels. The present stopes above the latter level show no change from the average dip. On the other hand, ten to twenty feet to the south of William's Lode occurs another vein known as South Lode, shown only approximately in the section (Plate I) at the 20-fathom level, since no data were available from the mine plans. Where it can be examined, it appears to strike somewhat more to the east than does William's Lode, and to dip almost vertically to the th. It would appear, then, that the lode seen in dit is really a part of the South Lode or of

some small vein at present otherwise unknown. The exposures in the adit level (twenty-seven fathoms below surface), as far as they were accessible, were examined by the author without the detection of any definite characteristics to suggest their connection with William's Lode rather than with any other lode.

The Engine Lode is a thin, poor vein shown in the section (Plate I) to the north of William's Lode, dipping to the north. It strikes east of north-east, and passes through William's Lode without faulting it or being itself faulted. At the junction there has always been found an enrichment of tin values. It does not heave the Great Flat Lode, the supposed junction showing only a joint running across the hanging wall of one of the stopes on that lode.

The West Basset Lode, to the south of William's Lode, dips to the north at a high angle. It is said to have yielded copper sulphides in a veinstone of quartz, peach, and killas, and at 120 fathoms west of Grenville shaft to heave the Great Flat Lode ten fathoms.* It has not been examined by the author.

The Great Flat Lode has already been sufficiently described by numerous authors.† It is faulted by William's Lode and by West Basset Lode. Its average strike throughout its whole length is

* D. A. MacAlister: "Geology of Falmouth and Camborne, etc.," *Mem. Geol. Survey* (1906), p. 239.

† C. Le Neve Foster: "On the Great Flat Lode," *Q. J. G. S.*, Vol. XXXIV (1878), p. 640. D. A. MacAlister: "Geology of Falmouth and Camborne, etc.," *Mem. Geol. Survey* (1906), pp. 130, 139, 150–3, 163, 177–8. J. H. Collins: "Observations on the West of England Mining Region" (1912), pp. 142, 201.

E. 34° N. In King Edward Mine it dips to the south at about 35° in the upper levels, getting steeper with depth. Its junction with William's Lode may be seen in the 50 and 60 fathom levels, and is an overthrust fault, the Great Flat Lode being thrown on the east about five fathoms to the north (Fig. 1 and Plate I).

William's Lode has not been followed down below its junction with the Flat Lode in this mine, but in West Wheal Frances a cross-cut was driven in to it below the Flat Lode, and it was found to be only a joint in the granite. Further work was then stopped, but it is possible that the lode had only pinched at the point where it was struck, and might have been found to open out again had it been further explored.*

It is the opinion of Mr. J. C. Shepherd, the manager of King Edward Mine, that the lode shown in the section (Plate I) south of King's shaft between the 93 and 103 fathom levels is very possibly the downward continuation of William's Lode.

In the exposures examined by the author William's Lode is found to vary greatly in width throughout the mine, but it probably averages about thirty inches; it frequently sends out small branches and stringers into the surrounding rock, or it may split into two, enclosing small horses of granite. On the whole, it is fairly sharply separated from the country rock, but in places it may merge into it

* Verbal communication from Captain Kit Bennetts.

more or less insensibly. Similarly to other Cornish tin lodes it occupies an irregular fissure running through the granite and the neighbouring killas.

It is everywhere traversed by longitudinal joints, which sometimes form smooth polished walls called "slickensides" by the miners. They show, however, no definite signs of striation, and do not conform to the strict scientific meaning of the word. These joints are usually smeared over with a green chloritic mineral, except in the upper levels where the chlorite is usually replaced by iron oxides and clay. They occur also in the neighbouring granite; and, in a stope above the 20-fathom level, where there is a small exposure of aplite in the north wall, it also is traversed by these joints to such an extent that it appears as a smooth green wall, the fact that it is aplite being revealed only on breaking out a piece.

Similar jointing has been described by Mr. J. H. Collins* under the name "sheeted structure," which most aptly explains its general appearance in the mine. He says: "This occurs at times in the lode itself and also in the country adjoining the lode. It is no doubt a shear structure. . . . The lode-filling and the enclosing rock are traversed by numerous longitudinal joints, parallel to the lode walls, in such a way as to produce many 'false walls,' which often mislead the miner in his underground labours, leading him to think that he has broken down all the

* J. H. Collins: "The West of England Mining Region" (1912), p. 104.

payable ground, when, in fact, much still remains unbroken."

There are also numerous small, vertical and horizontal joints running transversely to the walls of the lode, but they do not persist for more than about a foot.

The lode is also slightly disturbed by small faults and cross-courses striking roughly north and south.

Numerous small, irregular quartz veins traverse both the lode and the surrounding country in all directions. Some of these, again, have been faulted on a minute scale by joints in the granite, so that hand specimens may be obtained showing a complete fault.

Aplite dykes are exposed in the walls of William's and of South lodes; they have been, in places, highly silicified by these lodes, and must therefore have formed previously to them. At the junction of Engine and William's lodes in the 30-fathom level an exposure of aplite may be seen in the south wall; it appears to have been faulted down to the east by one or both of these lodes, since it does not appear again in the drive on William's Lode until forty feet east of the junction, when it rises gradually from the floor of the level, and finally disappears in the roof twenty-five feet further east. It appears to be striking roughly N.N.E. and dipping at a low angle to the W.N.W. Its thickness is about three feet. The lode in passing through it splits up into numerous small stringers.

COMPOSITION OF THE LODE.

I. *Minerals of the Lode.*—The minerals in the lode may be divided into three classes according to their supposed mode of origin.

1. Those of supposed primary origin:—

   Cassiterite.
   Quartz.
   Tourmaline.
   Chlorite (mostly).
   Iron Pyrites.
   Chalcopyrite.

2. Those due to secondary alterations:—

   Iron Oxides.
   Sericite.
   Clayey material, generally misnamed "kaolin."
   Chlorite (in part).
   Cuprite, native copper, malachite, and various sulphates of iron and copper which stain the walls of the levels.

3. Those due to inclusions of country rock:—

   Quartz.
   Felspar.
   Muscovite.
   Cordierite (?).
   Tourmaline (in part).

The cassiterite, when visible to the naked eye, occurs either as small black or brown crystals with an adamantine lustre, or as small grains intimately mixed with quartz, the whole being of a light brownish colour. Under the microscope it appears, as a rule, in euhedral prismatic crystals giving

squarish cross-sections; when cut more nearly parallel to the main crystallographic axis it is found to be terminated at one end by a pyramid, sometimes remarkably acute, the other end being generally an irregular surface. Doubly terminated crystals occur, however, but are usually minute. Twins are by no means rare, and a few may generally be noticed in a section showing much cassiterite. It shows the usual physical characters: high refraction and birefringence, colour-zoning, slight pleochroism, etc., and appears to have always been one of the first minerals to crystallise from solution. Titanium has been reported as a constituent of the cassiterite from William's Lode; it is probably present as rutile, or as the tetragonal form of $FeTiO_3$.*

The quartz, by far the most plentiful mineral in the lode, occurs either intimately associated with the other minerals or as small veins. Little hexagonal crystals may be found lining cavities, but it generally occurs in anhedral grains frequently showing signs of brecciation and undulatory extinction when viewed between crossed nicols. Thin veins of this material may be found in places reduced to skeletal quartz, showing that it has been attacked and dissolved by solutions since its formation. This is found only on a very small scale, and generally in the centre of the lode, which seems at the present time to be the main channel for descending surface waters.

* Cf. W. T. Schaller: "The Rutile Group." Mineralogical Notes, Series 2. *Bull. U.S. Geol. Survey*, No. 509 (1912).

Tourmaline, one of the main constituents of the lode, is present in two distinct varieties: as small blue needles enclosed in quartz, and in larger crystals or crystal fragments of a brown colour, frequently with a blue edging or showing colour-zoning. It may be seen lining joints in a stope above the 20-fathom level, where blue "peach" is present in much greater quantity than usual (see Fig. 2).

Chlorite appears, on the whole, to be commoner than tourmaline; it occurs in small flakes and sheaves sometimes distinctly visible to the naked eye, and often fills pockets in the centre of the lode. In the slides it is often in fan-shaped radiating aggregates, or as a felted mass of small sheaves, and is distinctly pleochroic. It also frequently lines joints both in the lode and the neighbouring country rock, when it appears as a greenish smear.

Iron pyrites and chalcopyrite may be seen in small quantity in the lower levels. They appear to have entered the lode only at a late period in its history. Copper is not present in the workings in sufficient amount to be of any value, though it affects the quality of the dressed tin, and it has been found profitable to leach it out of the concentrates and precipitate it on scrap iron.

From an old longitudinal section on William's Lode (Plate II) it appears that the old workings could be divided into areas of "tin ground" and "copper ground," the tin ground occurring to the east of the copper. The present workings, which are in tin ground, do not appear in the section, being

further to the east. It has not been proved whether the copper gives place to tin with increased depth, since at the present time no work is being done in or below that portion of the lode shown in the section. According, however, to Mr. D. A. MacAlister* "black and yellow copper ores and native copper were found alongside of tin in the Middle [William's] Lode . . . at South Condurrow Mine, but only to the 70-fathom level."

Of the minerals produced by atmospheric weathering the iron oxides and the so-called "kaolin" decrease very markedly in the lower levels. The iron oxides may be hematite, limonite, or any intermediate variety, and neither they nor the clay material call for special mention in this place.

Much of the chlorite lining joints and small faults in the lode is probably secondary, and may be derived from almost any ferro-magnesian mineral, apparently in this case chiefly tourmaline.

The cuprite occurs in small octahedrons of a port-wine colour, with an adamantine, somewhat resinous lustre, rapidly turning black on exposure to light. It is sometimes associated with native copper, which may occur also separately, but seems always to be accompanied by iron oxide.

The minerals of Class 3 call for no special mention, except to point out that they are often much brecciated and altered as a result of the attacks of

* D. A. MacAlister: "Cross-section and some Notes on the Tin and Copper Deposits of Camborne," *Trans. Roy. Geol. Soc. Corn.*, Vol. XII, Part IX (1903).

mineralizing solutions and repeated crushings to which they have been subjected.

II. *Types of Veinstone.*—There are two main types of veinstone: (*a*) a fine-grained siliceous, often compact, rock known as "peach," and (*b*) an altered granite or "capel." Both varieties may contain either tourmaline or chlorite, but sometimes, as a result of the secondary infiltration of chlorite or of the alteration of tourmaline, both minerals may occur in the same specimen.

The tourmaline peach is sometimes a hard and compact blue rock, not showing definite crystals of tourmaline except under the microscope, but it is more generally highly siliceous and then appears dark grey in colour. A specimen of this quartzitic rock obtained from a stope between the 10 and 20 fathom levels, when examined under the microscope, showed highly brecciated quartz fragments, minutely veined and infiltrated with tourmaline and some quartz. A few larger, brown crystals of tourmaline, showing colour-zoning, were also present in the slide. The blue colouration tended to occur round the edges, and to follow cracks in the mineral, and seems to be due to some form of secondary alteration. Ragged pieces of muscovite were rare, and cassiterite was not observed.

A hard grey siliceous rock from the 40-fathom level, with cassiterite visible in the hand specimen, proved on microscopical examination to contain brecciated fragments of blue peach sealed by an intrusion of quartz and cassiterite. The quartz is

often hypidiomorphic, and seems in general to have crystallized before the cassiterite which occurs round its edges in lines of small crystals. On these, again, later quartz has often been laid down sometimes in optical continuity with the older. In one place in the slide three generations of quartz were seen separated from each other by borders composed of small cassiterite grains. This may be the result of resorption during crystallization from solution and may not necessarily denote three separate invasions.* Minute leaves of chlorite are rare. It is possible, but not absolutely clear from the slide, that between the brecciation of the tourmaline peach and the introduction of quartz and cassiterite there was another formation of tourmaline peach fairly rich in cassiterite which was itself brecciated and intimately mixed up with the older rock.

A specimen from the 30-fathom level, showing minute crystals of cassiterite lining a grey quartzose vein in green peach, with fragments of milky quartz, was seen in thin section to have been much brecciated; blue peach containing broken fragments of quartz and chlorite had been invaded by quartz veins carrying a little chlorite. At one side of the slide occurred a large patch of cassiterite, deeply stained with iron oxide, which was thought to be secondary.

The green peach may occur as a dense compact rock with a few fragments of quartz, or more often as a dark green rock of somewhat coarser texture

* Cf. A. Harker: "The Natural History of Igneous Rocks" (1909), p. 231.

showing under a lens, and occasionally also to the naked eye, distinct flakes of chlorite. It appears in the main to have been introduced at a later period than the blue peach, and is itself brecciated by still later quartz veins carrying sulphides of copper and iron. Under the microscope it is seen to consist chiefly of chlorite and quartz with some cassiterite, occasional fragments of tourmaline, and, rarely, sulphides of iron and copper.

A slide cut from a stringer of green peach, running out from the lode into the country at the 30-fathom level, showed green pleochroic chlorite, in places giving rise to magnetite. Two generations seemed to be present, the first in rather large laths and fan-shaped aggregates, sometimes enclosed in quartz, the second in a much finer grained felted mass frequently outlining the quartz, and surrounding the older chlorite. Quartz in fair-sized anhedral grains, sometimes broken up into a number of brecciated fragments, enclosed a few small needles of tourmaline and crystals of cassiterite. The latter mineral also occurred with the chlorite, which enclosed a few small crystals of tourmaline showing colour-zoning. Chalcopyrite intergrown with pyrites was present in one place.

Another example from the 40-fathom level showed, in the hand specimen, green peach somewhat brecciated and veined with quartz carrying sulphides. In thin section, green peach, composed of fine-grained chlorite and quartz with a small proportion of cassiterite, was seen to have been broken

up and invaded by quartz carrying chalcopyrite and iron pyrites, the latter being occasionally oxidized to limonite. A small amount of chlorite seemed to have been brought up with the quartz, and to have crystallized in cracks in the older peach and round its edges.

Filling, or partly filling, a vugh in the roof of the 40-fathom level there occurred a mass of green peach of a highly cavernous sponge-like texture, the cavities being filled with wet yellow ferruginous clay, and studded with small crystals of cuprite. Under the microscope it was seen to represent one invasion of quartz, chlorite, and cassiterite, with the after addition of a little secondary quartz and chlorite, infiltrated into cracks. The slide was very rich in cassiterite in well-formed prisms, sometimes twinned. Of the two other minerals the quartz seemed on the whole to have crystallized earlier, although it occasionally enclosed small blades of chlorite.

The "capel," which, like the peach, may be either green or blue, according to whether chlorite or tourmaline forms its chief ferro-magnesian constituent, is an altered granite, in extreme cases a quartz-tourmaline or quartz-chlorite rock, but showing all variations between these and the ordinary granite of the country.

Three specimens were microscopically examined; the first, a specimen of blue capel from the 20-fathom level, was made up of large brecciated fragments of quartz, bound together by a fine-grained

matrix of quartz and tourmaline. Some larger crystals of tourmaline showing the usual colour-zoning were also present.

A green capel from a stope above the 20-fathom level appeared, in thin section, very similar to the last, except that, in the cement, chlorite takes the place of tourmaline. Some cassiterite was present, and large somewhat ragged pieces of tourmaline again occurred with, in at least one instance, distinct brecciation. The quartz is not quite so broken up as in the blue capel, but occasionally shows undulatory extinction, and contains small inclusions of sericite and other undetermined minerals.

The third specimen was a highly altered granite from the south side of the lode in the 40-fathom level, perhaps better described as a felspathic capel. An examination of the slide showed that the granite had been broken up and impregnated with quartz, chlorite, and cassiterite. The original quartz was brecciated into irregular fragments showing strain shadows, the felspar appeared cloudy and was much cracked and invaded along cleavages by chlorite, and was also slightly sericitized. Other minerals present were occasional muscovite with ragged edges and a large cube of pyrites.

The difference between capel and the more siliceous varieties of peach is perhaps best understood from a consideration of the conditions existing when the lode was formed. The crack in the granite, now forming William's Lode, is supposed to have been one of many caused by

a series of earth movements which took place at a late stage of igneous activity. It did not form as a sharp, clean fissure bounded by good walls, but was accompanied by differential movement of the two sides and some subsidiary fissuring, causing particles of rock from the sides to fall into it and become brecciated. At the same time, or very shortly after, solutions or vapours were introduced and impregnated the whole mass of crushed rock. Where they found open spaces they formed dense peach; where they found much fine dust and broken fragments from the walls they formed a fine siliceous peach with some larger quartz fragments, the felspars and ferro-magnesians of the rock being dissolved or so altered as to have become unrecognizable; while, where the granite of the walls was only cracked, they followed these cracks and impregnated the neighbouring rock, forming capel where the cracks were numerous, and the altered granite of the country where the cracks were fewer. Naturally all intermediate varieties between the two extremes are to be expected and do actually occur, though not all at the same place in the lode, which differs very markedly from the Great Flat Lode in the comparative sharpness of its walls.

The leader, as far as could be seen, is always a quartz vein; it is frequently iron-stained, and appears at the present time to be the main channel for surface waters descending the lode. In the upper levels a vein of ferruginous clay or earthy hematite may occur with it and obscure its presence,

especially if the enclosing rock has been much kaolinized and iron-stained. It varies in width from a mere joint up to six or eight inches, and may split into separate veins. In the lower levels it may often be seen to carry copper and iron sulphides. In the upper levels, if the peach which is often found occurring with it has become much softened and iron-stained, the whole may become confused and indistinguishable, and is then frequently referred to as a clay leader. In this condition it often carries much cassiterite. In places the whole lode may pinch out until nothing remains but a thin quartz vein separated from the barren granite by thin walls of capel.

NATURE OF THE COUNTRY ROCK.

All the present workings are in granite. This granite varies in hardness from point to point in the mine, often it is fairly hard when first opened up, but softens after a time on exposure to the air and damp of the levels.

The felspars are generally white, occasionally pinkish, and almost invariably appear in the hand specimen to be kaolinized; under the microscope, however, it is seen that true kaolin is rare, if not altogether absent, and that their decomposition is the result of sericitization.

Quartz, white mica, and tourmaline appear to be the other original constituents. The absence of biotite is noteworthy. The rock is frequently

traversed by branches and stringers running out from the lode in all directions.

In a stope between the 10 and 20 fathom levels there occurs a more or less oval patch (see Fig. 4) of a rock consisting of kaolin, quartz, and tourmaline. White mica is rare. This patch occurs about a foot or eighteen inches to the south of the lode, which in this place has been allowed to get somewhat into the footwall of the stope. It is sharply separated from the surrounding country, which as usual contains white mica, chlorite, and only a little tourmaline, while chlorite is entirely absent from the kaolin rock, and white mica is not very conspicuous. Around the border is a rim of varying width, which has been stained different shades of yellow and brown by iron oxide. In the central part, however, the kaolin is perfectly white and so soft that it may be dug out with the fingers. The quartz occurs in rounded grains as in granites, while the tourmaline is aggregated into bundles of acicular crystals scattered through the rock, and is thought to be replacing the biotite of the original granite. This central part is separated from the iron-stained border by a distinct rim of iron oxide, which may or may not (but generally does) follow thin veins of quartz and tourmaline.

A sample of this rock was taken and dried over a water-bath, fifty grammes of the dried powder were then weighed up and the kaolin was washed out with water. The residue was weighed and examined and found to consist of quartz and tourmaline. No

other minerals were seen except some white mica in exceedingly fine grains which washed away with the kaolin. The kaolin (together with such white mica as accompanied it) was found to constitute over 46 per cent of the rock.

In the upper levels of the mine the country is much softer and is both more clayey and more iron-stained than in the lower levels. In the stope above the 10-fathom drive there occurs on the hanging wall of the lode a pinkish rock of somewhat porcellanous appearance, showing a few small crystals, or crystal aggregates, of tourmaline, and traversed by thin quartz veins. It was found, in thin section, to consist chiefly of large masses of felspar undergoing alteration; under a high power (magnified 400 dia.) this felspar is seen to be full of minute blue tourmaline needles in places segregated into dense clusters, which appear as brown dust under a lower magnification. Irregular mosaics of quartz with inclusions of tourmaline and sericite, sometimes in such quantity as to give the whole a cloudy appearance, seem to represent an extreme stage in the alteration of this mineral. The rock has been invaded by quartz veins carrying cassiterite, which appears as small sub-idiomorphic crystals intimately associated with the quartz, although a few minute grains may also be seen in the felspar. In addition to the fine tourmaline needles larger crystals of the same mineral are present with characteristic colour-zoning, and showing, in places, ragged edges. They are possibly derived from biotite. A certain amount of

biotite exists in the slide, in most cases outlining the quartz, but also, in places, staining the felspar. A few grains of a pale green, almost colourless, isotropic mineral were supposed to be fluorspar. It is the opinion of Mr. Hall, who also has examined this slide, that it exhibits the preliminary stages of tourmalinization of the felspar, a process which may be well seen in specimens of the rock known as trevalganite.*

Horses of granite may be enclosed between two branches of the lode; a specimen from such an included mass was found on microscopical examination to consist of allotriomorphic quartz in large grains with undulatory extinction, a negative biaxial mineral very similar in general appearance and strength of birefringence to the quartz and showing signs of strain, which was considered to be cordierite, felspar partly altered to sericite and quartz, ragged flakes of muscovite, green chlorite, often containing small undetermined inclusions (possibly zircons) surrounded by pleochroic halos, and sometimes intergrown with muscovite, much secondary micaceous material thought to be either pinite after cordierite or sericite after felspar, and a single crystal of brown tourmaline. Much of the chlorite is undoubtedly after biotite, but a certain amount seems to be intimately associated with the fine-grained micaceous material, and may be derived from the same mineral or minerals as this latter.

* For description of trevalganite see Flett: "Summary of Progress for 1903," *Mem. Geol. Survey*, p. 157. Reid and Flett: "Geol. Land's End," *Mem. Geol. Survey* (1907), p. 55.

A specimen of the country rock from the 30-fathom level was also examined. The slide showed large irregular grains of quartz exhibiting signs of strain, ragged pieces of muscovite, cloudy felspar partly kaolinized, small leaves of distinctly pleochroic chlorite, sometimes partly or completely enclosed in the felspar, sometimes intergrown with the muscovite or, again, occurring as separate flakes, with pleochroic halos, presumably after biotite. Tourmaline was present in small quantity, either enclosed in, or lining, grains of quartz. Cassiterite, in small crystal grains, generally associated with chlorite, and sometimes showing colour-zoning, was scattered sparsely through the slide.

The granite in the neighbourhood of the lode differs from that seen on the surface, not only in the absence of biotite and its replacement by chlorite or tourmaline, but also in the greater alteration of the felspars, generally described as kaolinization, and supposed to be due to the action of pneumatolytic vapours which accompanied the introduction of the cassiterite.

In what measure, however, this is due to magmatic vapours or solutions, and in what to the fact that the lodes are very favourable channels for the circulation of surface waters cannot be certainly determined. The author is inclined to the opinion that surface waters are responsible for by far the greater proportion, as seems to be shown by the gradual hardening of the rock in depth.

It should be remembered that very little of the

soft clayey substance found in the mine, and generally described as kaolin, has advanced further than the sericite stage in the alteration; it is otherwise, however, with the small patch of rock consisting of soft white kaolin, quartz, tourmaline, and a small amount of white mica, which has already been described as occurring in an oval-shaped pocket in a stope between the 10 and 20 fathom levels. In this rock the kaolin substance contains a large proportion of true kaolinite, and appears to owe its origin to true magmatic causes.

It seems to have originated as a segregation of carbon dioxide, steam, boric acid, and perhaps fluorine, in the cooling magma. The granite surrounding the segregation having already solidified, and the still molten portion being unable to force its way out, the boric acid combined with the lime, iron, and magnesia to form tourmaline; the water and carbonic acid attacked the already formed, or forming, felspar and produced kaolin, potassium carbonate, and quartz; while the fluorine, if any were present, produced white mica and topaz. If fluorine were present only in small quantity it would possibly go into the tourmaline. No topaz was observed in the samples.

From the pocket-shaped nature of the occurrence and its distinct differentiation from the surrounding rock it appears that the agents which caused the alteration remained for some time in the place affected, and it is not clear, had they been introduced from the lode, how they would have caused

such intense alteration in only one pocket. It seems more probable that, had they come up in a fissure, the walls would show kaolinization practically throughout their length with a progressive decrease in the alteration with distance from the vein.

ORIGIN OF THE MINERALS IN THE LODE.

From a consideration of the sections in the mine (cf. Figs. 2–8) it seems clear that the blue peach was formed before the green peach, and that last of all came an introduction of quartz carrying sulphides of iron and copper.

From an examination of the few slides that the author has been able to have prepared, the details of the history of the lode seem to be somewhat as follows :—*

I. A fissure was opened, and possibly invaded by quartz.

II. The fissure was reopened with movement of the walls and brecciation of the already formed quartz, and a mixture of quartz, tourmaline, and cassiterite was introduced. It is not unlikely that the brecciated quartz fragments found in this blue peach may, in part, represent merely broken pieces of granite, fallen in from the walls when the fissure opened, the felspar and ferro-magnesians having, as a rule, been so altered as to be unrecognizable as such ; occasionally fragments of much altered felspar

* Cf. J. S. Flett : "Brecciated Stanniferous Veinstones." Summary of Progress for 1902. *Mem. Geol. Survey* (1903), p. 154.

may be found. The fact that a thin quartz vein already existed would not prevent fragments of the granite falling into the fissure when it was again opened.

III. The fissure was again opened, the blue peach brecciated, and quartz, chlorite, and cassiterite were introduced.

IV. There was a slight renewed movement, the already deposited green peach being slightly brecciated and invaded by quartz, tourmaline, and a small amount of cassiterite. This intrusion seems to have been small and of slight importance.

V. A further introduction of quartz, chlorite, and cassiterite, and possibly some sulphides. The green peach is often of a somewhat open texture, and it is possible that where in the slides pyrites and chalcopyrite appear to be imbedded in it, they really made their appearance at a later date.

VI. Brecciation of the green peach, and invasion of quartz carrying chalcopyrite and pyrites. There is no sign that any cassiterite was brought in with this last intrusion.

VII. After a long period of rest the lode was disturbed and intersected by a series of faults and cross courses striking roughly north and south.

It is possible, but not absolutely certain from the slides, that between Stages II and III there was another introduction of tourmaline, quartz, and cassiterite.

The exact sequence of the events is often somewhat difficult to make out, since the fissure did not

as a rule open in the centre of a former deposit, but frequently to one side or the other, so that the first intrusion of blue peach may be found brecciated by the last intrusion of green peach. Further, where there was a gaping fissure at the time when, say, quartz and tourmaline were introduced, with the consequent deposition of much blue peach, at the time of the later intrusions the fissure may here have been a mere crack, so that the green peach is only a thin vein or even absent altogether.

The events that have been chronicled above seem to point to a gradual change from acid to alkaline solutions. There was apparently also a much greater proportion of water in the later intrusions.

It is highly probable that the tin was brought up as either a fluoride or a borate.* Topaz, however, has not been observed in any of the slides, while tourmaline occurs in large amount in the blue peach and in small quantity in the green peach. It seems, therefore, that the tin was in the form of a borate.† In this connection the occurrence of a rare borate of tin and calcium reported by Brögger‡ from a dyke of elæolite-syenite is of interest.

At a later period, owing possibly to the large amount of magmatic water present, chlorite was formed apparently at the expense of tourmaline, the boron being carried away either as boric acid or a soluble borate. The presence of boric acid in hot

* D. A. MacAlister: "Geology of Falmouth and Camborne, etc.,' *Mem. Geol. Survey* (1906), pp. 167–71.

† Cf. D. A. MacAlister: *Q. J. G. S.*, Vol. 59 (1903), p. 53.

‡ W. C. Brogger: *Zeitschr. Kryst. Min.*, Vol. XVI (1890), p. 61.

springs in volcanic regions is a matter of frequent observation, the famous examples in Tuscany being well known. It has been suggested by E. Perrone* and R. Nasini† that the Tuscan boric acid is derived from the decomposition of tourmaline by water. Discussing the chlorites F. W. Clarke‡ says they are always of secondary origin, and only appear in volcanic rocks as the result of hydrothermal alteration. He further states that any aluminous ferromagnesian mineral may be thus altered to chlorite. Some of the chlorite in the mine is undoubtedly due to the secondary alteration of tourmaline by descending atmospheric waters. But these agencies only account for a very small proportion of it; by far the greater amount, including all that forming the green peach, was undoubtedly deposited at the same time as the quartz and cassiterite so intimately associated with it. The conditions which decide whether tourmaline or chlorite is to be deposited have, as far as the author is aware, not yet been worked out, but in all probability the presence or absence of large quantities of magmatic water was of the first importance. There is nothing to suggest that the supply of boron ran short in any way; it was probably present in quantity in all the intrusions except the last, that is, it was present with all the intrusions that carried cassiterite.

The chlorite in the country rock will owe its

* *Carte idiographica d' Italia*, No. 31 (1904), p. 355.

† *Atti. Accad. Lincei.* Fifth Series. Vol. XVII (1908), p. 43.

‡ "Data of Geochemistry." Ed. 2. *Bull. U.S. Geol. Survey*, No. 491 (1911), p. 378.

origin to both magmatic waters and to atmospheric solutions. It has generally been remarked that, in this district, the copper tends to occur in killas, while the tin occurs in the granite, the latter being deposited at a higher temperature than the former. This seems to be borne out in William's Lode, where at first, when the temperature was presumably at its highest, tin was deposited, while only the latest, and consequently coolest, intrusion carried copper in any quantity.

The actual temperature at which the intrusions took place is a question on which very little positive information seems to be obtainable. An experiment by K. Chrustschoff* may be here quoted as possibly suggestive. He added hydrofluoboric acid to an aqueous solution of colloidal silica at different temperatures, and obtained cristobalite between 180° and 228°, quartz between 240° and 300°, and tridymite between 310° and 360°. If this experiment may be supposed to represent the conditions of deposition of the quartz in William's Lode, it would seem to suggest that the temperature at which the blue peach was introduced lay somewhere between 240° and 300°. In this connection the apparent absence of fluorine minerals from the lode presents a difficulty. Owing to the presumed presence of large quantities of magmatic water in the later intrusions the temperature was probably considerably lower when the chlorite was deposited.

* *Neues Jahrbuch* (1897), Part I, p. 240.

SECONDARY ALTERATIONS IN THE LODE.

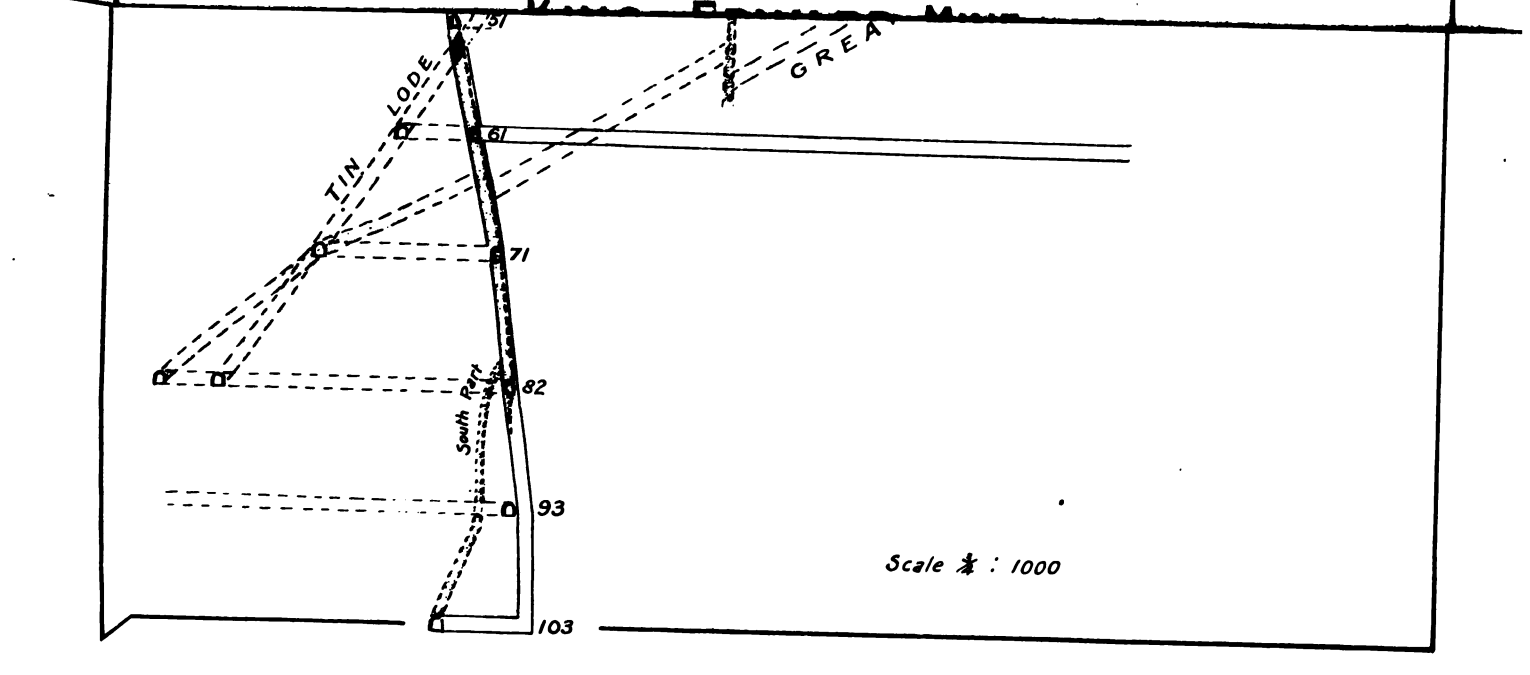
The most striking feature in the lode, due to secondary alteration, is the large amount of clay and iron oxides observed in the upper levels. The clay arises from the decomposition of the felspars, and possibly also from the chlorite, of both the lode and the surrounding country rock. The iron-oxide, which is due chiefly to the alteration of the ferro-magnesian minerals, and, to a less extent, to the oxidation of pyrites, stains the lode and the neighbouring country in the upper levels various shades of red and brown. In the lower levels its effects seem in general to be confined to the leader, or to that part of the lode which serves as the main channel for downward-moving surface waters. It frequently follows stringers running out from the lode into the country, staining the granite for some inches on either side of them. It is present in the mine water as sulphate often combined with copper. In old stopes and levels it is deposited as stalactitic growths of a brown limonitic material, and in standing waters of disused levels, or of old choked-up winzes, as a finely divided brown precipitate.

In one place small crystals of cassiterite with much hematite were seen lining a crack in the vein. On microscopical examination they were found to be of much later origin than the rock on which they were situated, minute veinlets of quartz traversing the slide being suddenly cut off on reaching the cassiterite. They are thought consequently to owe

PLATE 1

TRANSVERSE SECTION OF THE LODES

IN



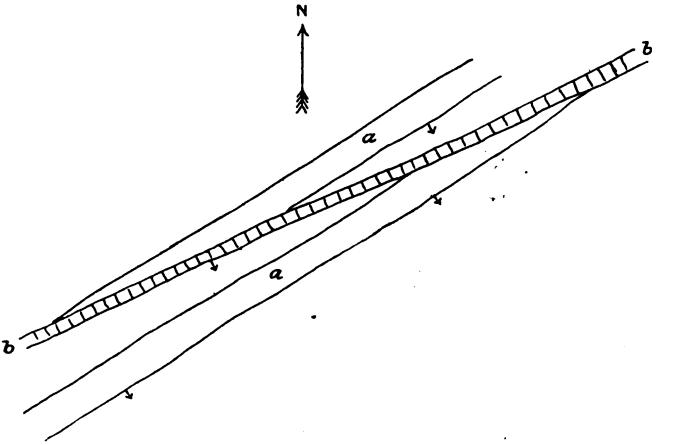


FIG. 1.—Diagrammatic plan of junction of William's and Great Flat Lodes, King Edward Mine, 60-fathom level.
a. Great Flat Lode. *b.* William's Lode.

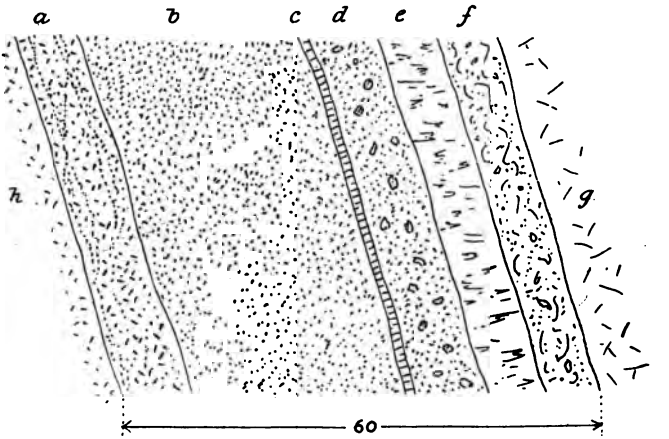


FIG. 2.—Section in stope above 20-fathom level. William's Lode, King Edward Mine.

a. Silicified aplite with stringers of blue peach.
b. Blue peach.
c. Iron-stained quartz vein. "Leader."
d. Blue peach with fragmentary quartz.
e. Ferruginous clay with quartz.
f. Capel.
g. Granite country.
h. Aplite.

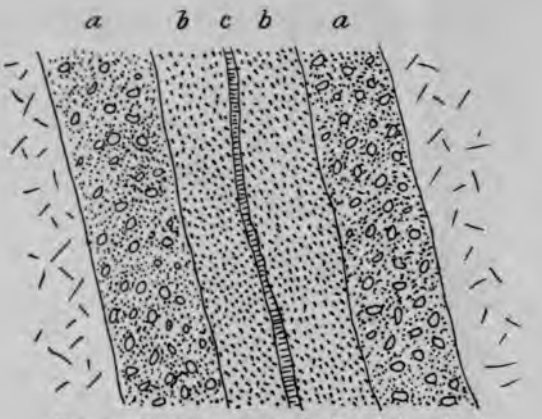


FIG. 3.—Section at east end of 40-fathom level.
William's Lode, King Edward Mine.
a. Blue capel. *b.* Green peach.
c. Quartz leader carrying sulphides.

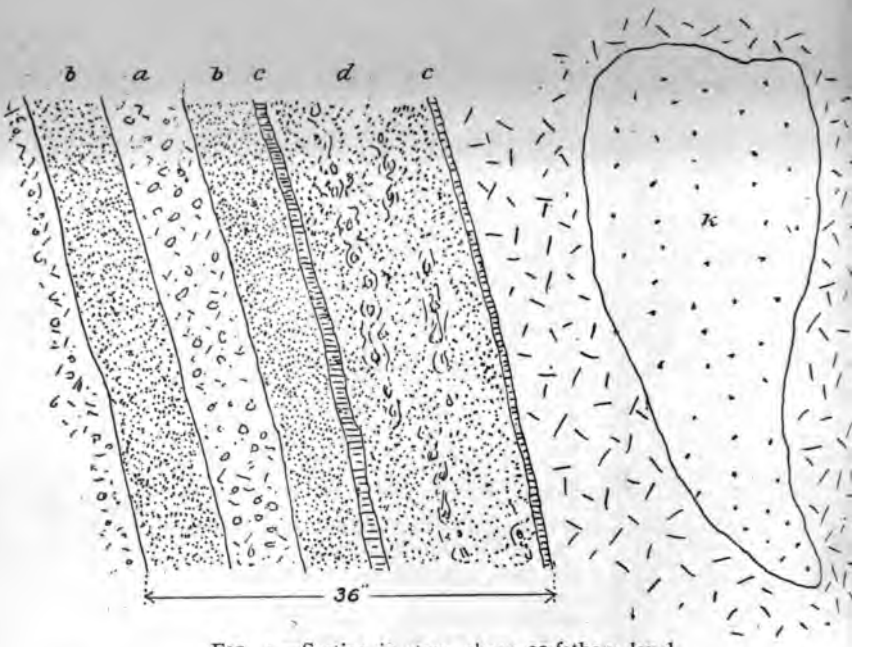


FIG. 4.—Section in stope above 20-fathom level.
William's Lode, King Edward Mine.
a. Felspathic capel. *b.* Blue peach. *c.* Iron-stained quartz vein. "Leader."
d. Blue peach with fragments of altered country (capel). *k.* Kaolinized granite.

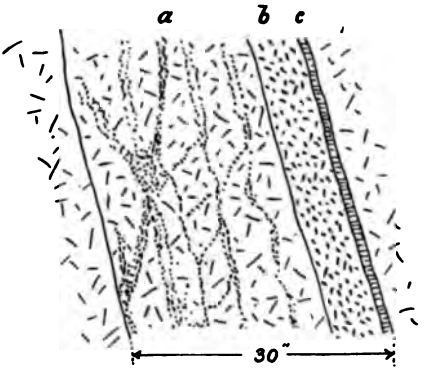


FIG. 5.—Section in stope above 30-fathom level. William's Lode, King Edward Mine.

a. Altered granite with stringers of blue peach.
b. Green peach.
c. Iron-stained quartz vein. "Leader."

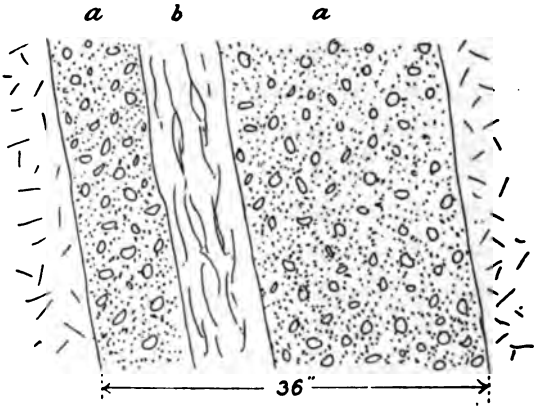


FIG. 6.—Section in stope above 30-fathom level. William's Lode, King Edward Mine.

a. Capel. *b.* Quartz vein with streaks of chlorite.

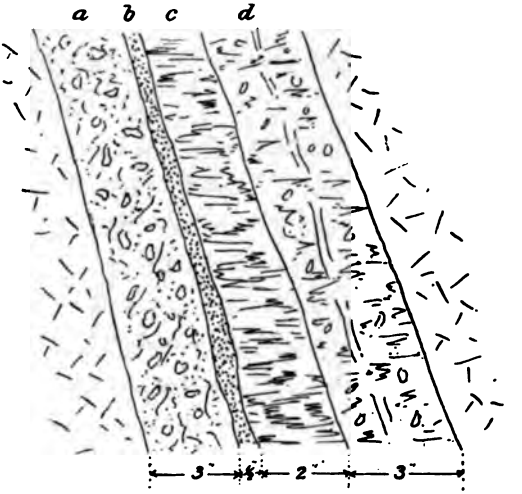


FIG. 7.—Section at east end of 10-fathom level. William's Lode, King Edward Mine.

a. Green capel much iron-stained.
b. Vein of blue peach.
c. Clay leader (stanniferous red and white clay).
d. Green chloritic clay with quartz bands and fragments.

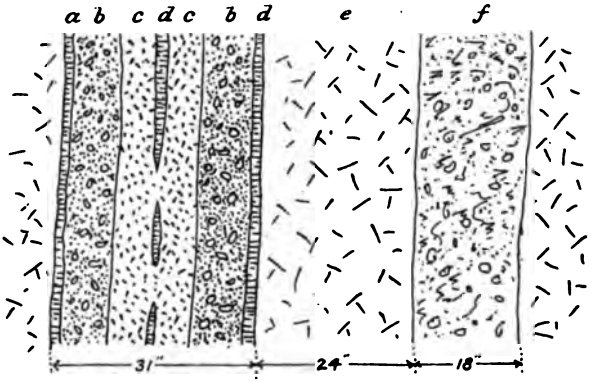
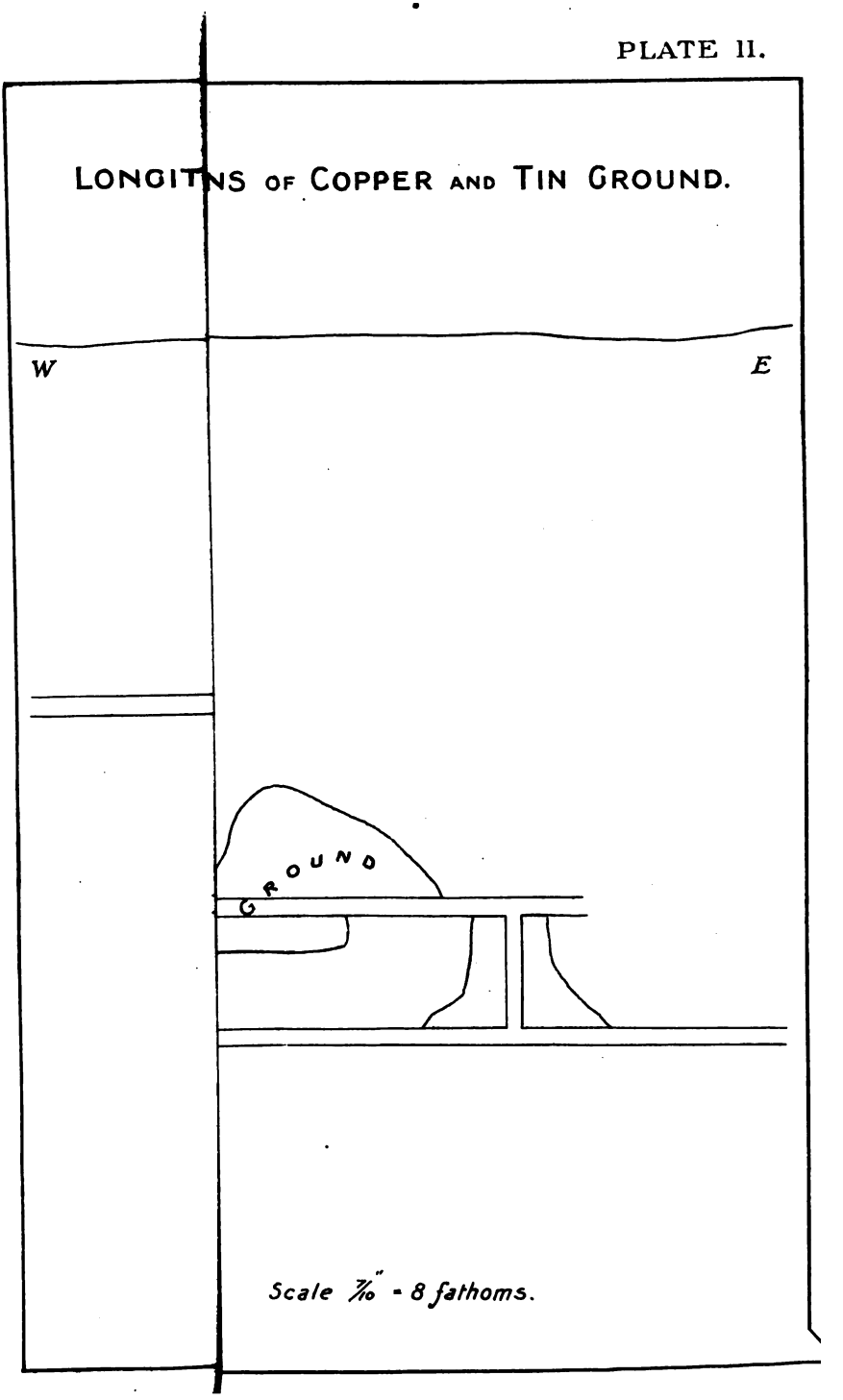
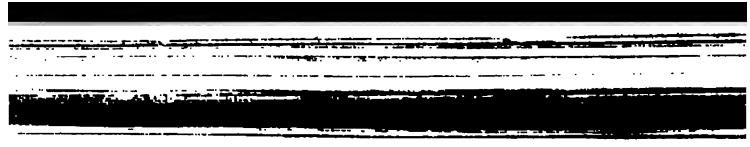


FIG. 8.—Section in 30-fathom level on William's Lode, 10 feet east of junction with Engine Lode, King Edward Mine.

a. Quartz vein.
b. Blue capel.
c. Green peach.
d. Irregular quartz veins carrying sulphides of copper and iron.
e. Granite.
f. Capel, much quartz-veined and iron-stained; contains brecciated quartz.

PLATE II.


LONGITUDINS OF COPPER AND TIN GROUND.
W
E
GROUND
Scale 7/10" = 8 fathoms.



their origin to secondary alteration, possibly to the oxidation of stannite,* cassiterite itself being a particularly stable mineral.

Native copper and cuprite are undoubtedly secondary in all their occurrences in this lode. They tend to occur in pockets, and appear to have been deposited from solution wherever a favourable situation was found. Specimens may be obtained from the 60-fathom level at the junction of William's Lode with the Great Flat Lode. These show cuprite in association with native copper and hematite, and indicate that surface waters have been effective in causing changes in the lode to at least a depth of 500 feet. The copper may occur without cuprite, and vice versa, but iron oxide seems to accompany them in all cases. Chalcocite, produced by the alteration of chalcopyrite, probably gave rise to cuprite according to the following reaction, first stated by Lindgren :—†

$$2Cu_2S + O = 2CuS + Cu_2O$$

The copper probably owes its origin to the reduction of cuprite by ferrous sulphate, or to reaction with sulphuric acid solutions.

The secondary alteration of tourmaline to chlorite, and the occurrence of a small amount of skeletal quartz, have already been noticed.

* Cf. F. W. Clarke: "The Data of Geochemistry," Ed. 2, *Bull. U.S. Geol. Survey*, No. 491 (1911), p. 653.

† Waldemar Lindgren: "The Copper Deposits of the Clifton-Morenci District, Arizona," *Prof. Paper, U.S. Geol. Survey*, No. 43 (1905), p. 11.

ORIGIN OF THE STRUCTURES IN THE LODE.

The brecciated character of the lode-contents and the fractures by which they are traversed have already been described, and the only structure which calls for special mention in this place is the series of longitudinal joints, the "sheeted structure" of Mr. Collins.*

Two points to be noted in connection with these joints are their smooth and frequently polished faces, and the absence of striations. Although they may be due in part to movements in the lode, this absence of striations seems to suggest that they are mainly due to some other cause, possibly to the alternate contraction and expansion in the already cooled rock effected by the heat of later intrusions. In this connection it may be remarked that they appear to be more frequent in the blue peach than in the later chlorite. On the other hand, it may appear more probable to many that they are the natural consequences of the cooling of a dyke-like intrusion, and their presence in the country rock is due to the fact that this also was heated up by the intrusions, points of equal temperature lying at roughly equal distances from the walls of the fissure.

In conclusion the author would like to express his indebtedness to Mr. J. C. Shepherd, the manager of King Edward Mine, for permission to

* J. H. Collins, *loc. cit.*

carry out the work underground, and to make use of the mine plans; and also to Mr. T. C. F. Hall for much valuable assistance in the preparation of this paper, and especially for the loan of numerous books of reference and papers bearing on the subject.

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